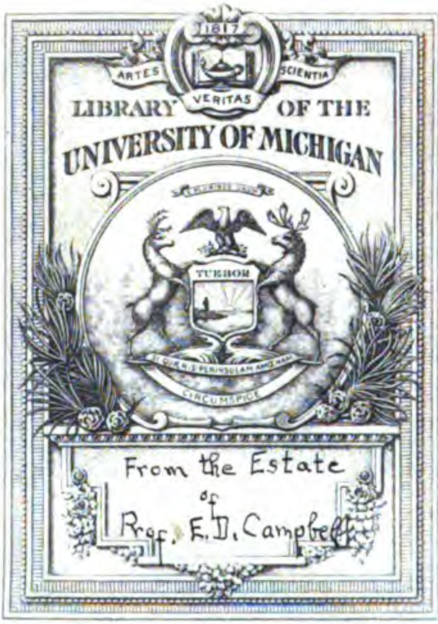
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METALLIFEROUS MINERALS
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A TREATISE ON

METALLIFEROUS MINERALS AND MINING

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BY

D. C. DAVIES, F.G.S.

MINING ENGINEER

AUTHOR OF 'A TREATISE ON SLATE AND SLATE QUARRYING' ETC.

Second Edition, carefully revised

LONDON

CROSBY LOCKWOOD AND CO.

7 STATIONERS'-HALL COURT, LUDGATE HILL

1881

From the estate of
Prof. E. N. Campbell
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PREFACE

TO

THE SECOND EDITION.

THE NECESSITY for a second edition of this book has enabled me to make several corrections and additions which will help towards its exactitude and completeness. I am pleased that these do not affect the truth of the general principles and inferences laid down or deduced in the book. Time will show, I think, that these principles and inferences are founded upon a true reading of world-wide geological phenomena, and are consequently in harmony with actual mining experience.

For the most part the book has been very favourably received by the press, and my reviewers will see that I have to some extent availed myself of their various suggestions and, in most cases, fair criticism.

The design of the book is stated in the Preface to the first edition, and it does not aim at anything beyond that purpose.

It simply seeks to set forth, for ordinary English readers, the substance of our knowledge on Metalliferous Minerals and Mining.

If it fulfils this purpose, it will achieve what I desire for it —a permanently useful place in English mining literature.

D. C. DAVIES.

EBNAL LODGE, GOBOWEN, OSWESTRY:
September 1880

PREFACE

TO

THE FIRST EDITION.

THIS BOOK is designed to describe, in a concise and systematic manner, the conditions under which metals and metallic ores are found in the different countries of the world.

It is hoped that such a description will serve, first, to explain to some extent the origin of deposits of metalliferous minerals; and, secondly, by defining the zones occupied by the various metallic ores, to lessen somewhat the amount of unsuccessful search for them.

My hope is that by the data given, together with the figures, quantities, and results contained in the book, the commercial conditions of mining success may be better defined.

The books referred to in the following pages show that there is no lack of mining literature, much of which is of a high order. Still, other persons may have felt, with myself, the want of a book covering the ground and fulfilling the purpose and plan of this volume. My endeavour in writing it has been to illustrate great principles by a sufficiency of representative details, and to refer the reader to sources where additional

illustration, as well as the enumeration of the minuter details of mining, may be found.

The explanations of scientific and of mining terms which are appended will, I hope, facilitate to ordinary readers the comprehension of the whole of the matters treated of.

The illustrations have been prepared by my son, Mr. E. Henry Davies, and my thanks are due to him for his willing and efficient co-operation.

My sincere wish is that this book may prove of real service to all those who are engaged in a profession which is as honourable when honestly followed as it is arduous and difficult in practice.

D. C. DAVIES.

EBNAL LODGE, GOBOWEN, OSWESTRY.

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CHAPTER I.

MATERIALS OF WHICH THE EARTH IS MADE.

List of Simple Elements—How distinguished and characterised—Metalliferous Minerals selected for description in this book—Table of Strata—General Geological Position of Metallic Minerals—Great Parallel Mountain Chains of the World.

THE materials of which the Earth is made are, in their combinations and variations, very numerous, amounting in all to about 600 species. When, however, these variations are analysed and resolved into their constituent parts, it is found that the whole of them, as far as at present known, are comprised within sixty-three simple elements, which, of course, cannot be further subdivided. The following is a list of the names of these elementary substances, together with the signs or abbreviations by which they are usually known :—

Aluminium	. Al.	Carbon .	. C.	Indium .	. In.
Antimony	. Sb.	Cerium .	. Ce.	Iodine .	. I.
Arsenic .	. As.	Chlorine.	. Cl.	IRIDIUM	. Ir.
Barium .	. Ba.	Chromium	. Cr.	IRON .	. Fe.
Beryllium	. Be.	Cobalt .	. Co.	Lanthanum	. La.
BISMUTH	. Bi.	COPPER .	. Cu.	LEAD .	. Pb.
Boron .	. B.	Didymium	. D.	Lithium .	. L.
Bromine.	. Br.	Erbium .	. E.	Magnesium	. Mg.
Cadmium	. Cd.	Fluorine.	. F.	Manganese	. Mn.
Cæsium .	. Cs.	GOLD .	. Au.	MERCURY	. Hg.
Calcium .	. Ca.	Hydrogen	. H.	Molybdenum	. Mo.

NICKEL .	. Ni.	Rubidium	. Rb.	Thallium	. Tl.
Niobium	. Nb.	Ruthenium	. Ru.	Thorium	. Th.
Nitrogen	. N.	Selenium	. Se.	TIN .	. Sn.
Osmium .	. Os.	SILVER .	. Ag.	Titanium	. Ti.
Oxygen .	. O.	Silicon .	. Si.	Tungsten	. W.
PALLADIUM	. Pd.	Sodium .	. Na.	Uranium	. U.
Phosphorus	. P.	Strontium	. Sr.	Vanadium	. V.
PLATINUM	. Pl.	Sulphur .	. S.	Yttrium .	. Y.
Potassium	. K.	Tantalum	. Ta.	ZINC .	. Zn.
Rhodium	. Rh.	TELLURIUM	. Te.	Zirconium	. Zr.

To which may now be added the substance named Gallium.

These elements, with their combinations, are distinguishable in a variety of ways, the principal of which may be summarised thus :—

1st. By their specific gravity or their relative weight to that of an equal bulk of water. For example—a cubic foot of iron is seven times heavier than a cubic foot of water, its specific gravity is therefore described as G (or gravity) = 7.

2nd. By their degrees of hardness, as compared with a given standard or gradation of substances. This gradation consists of the following substances, beginning with the softest and ending with the hardest :—

1. Talc.
2. Rock Salt.
3. Calcareous Spar.
4. Fluor Spar.
5. Apatite.
6. Adularia Felspar.
7. Rock Crystal.
8. Prismatic Topaz.
9. Corundum.
10. The Diamond.

Taking copper as an example, its hardness, varying from that of rock salt to that of calcareous spar, is described as H (or hardness) 2.5 ...3.

3rd. By their appearance and by their degrees of opaqueness or transparency: thus, quartz is described as 'lustre vitreous inclining to resinous, transparent or translucent, sometimes almost opaque.'

4th. By their colour, and the results yielded by them when tested under the blow-pipe. These properties are described in each case in words and not by signs.

5th. In the case of compound minerals, by their chemical composition, the study of which forms the basis of the science of Chemistry. A brief description of the compound minerals mentioned in the following pages, and which are not particularly described in the text, is given at the end of the book.

6th. By their tenacity, ductility, brittleness, and various fractural results. Thus gold is described as 'remarkably ductile and malleable,' and mercury as 'wholly volatile.'

7th. By the shapes they assume, or into which they crystallise when they have space and opportunity to do so. For it is found that each substance crystallises into one or two central forms, which have divergent but related variations in shape. Thus the primary form of felspar is a rhomboid, and that of quartz a six-sided prism ending in a pyramid. The science by which the shapes and internal structure assumed by minerals is studied and classified is called Crystallography, and it is a science which, from the combination of geometrical terms it employs, as well as from the almost innumerable divergences of substances from their central forms, is difficult to master.

8th. By their taste, as acid, sweet, etc.

9th. By their odour, as pungent, etc.; and

10th. By their solubility or otherwise when treated by acids.

The whole study of minerals by their characteristics is known as the science of Mineralogy, and the reader who desires to pursue the description of them further than is necessary for the purposes of this book, may consult the following works:—Nicols' *Mineralogy*; Dana's *Mineralogy*; or the more modern elementary book, *Rudiments of Mineralogy*, by A. Ramsay, jun.[1]

The sixty-three elementary substances may be broadly subdivided thus: Metals, forty-eight; Non-metals, fifteen. Of the latter, five are gases. Of the whole sixty-three, many of them are of very rare occurrence in nature, the bulk of the solid surface of the earth being made up for the most part of the five gases and the non-metallic minerals, oxygen and silicon being the preponderating substances.

[1] Crosby Lockwood and Co.

It is with the metallic minerals we have now chiefly to do, and I select from among them for description in this book, on account of their utility in ordinary life, the following, which in the foregoing list are printed in capitals—

Gold Silver Platinum Iridium Palladium	As the noble metals.
Copper Tin Lead Zinc Iron Nickel Mercury Bismuth Tellurium	As the useful metals.

These metalliferous minerals occur in nature in two distinct forms :—1st. Native, when they are found unalloyed with other and especially non-metallic substances, and are therefore pure and ready for use. 2nd. Mineralised, or associated with other minerals, and in combination with the gases or earthy admixtures. As we shall see, the latter, except in the case of the noble metals, is the common mode of occurrence. In this state they are known as 'ores,' which are still further distinguished by the prevailing ingredient of the mixture. For example, when metals are mixed chiefly with oxygen, they are called 'oxides;' when with the abundant mineral sulphur, 'sulphides;' and when with chlorine, 'chlorides;' all of which, with other combinations, we shall have to consider more particularly as we proceed.

The metallic minerals are of course found in the midst of the rocks, or strata, which form that part of the earth with which we are most familiar—its surface. The following table gives a list of these strata in the order in which they lie upon each other, and of the names by which the different groups of them

TABLE OF STRATA.

			Lower, Middle, and Upper
CAINOZOIC OR TERTIARY	*Recent.* POST PLIOCENE. NEWER PLIOCENE. OLDER PLIOCENE. MIOCENE. EOCENE.		
MESOZOIC OR SECONDARY	CRETACEOUS		Chalk. Upper Greensand. Gault. Lower Greensand.
	WEALDEN		Wealden. Purbeck Beds.
	OOLITE	Upper	Portland Oolite. Kimmeridge Clay.
		Middle	Coral Rag. Oxford Clay.
		Lower	Cornbrash. Forest Marble. Bath or Great Oolite. Stonesfield Slate. Inferior Oolite.
	LIAS		Upper Lias. Marlstone. Lower Lias.
	TRIAS		Rhaetic Beds. Keuper (New Red Marl). Bunter (New Red Sandstone).
PALÆOZOIC OR PRIMARY	PERMIAN	Upper	Dark Red Sandstones and Marls.
		Middle	Magnesian Limestones and Marls.
		Lower	Conglomerates, Breccias, and Red Marls.
	CARBONIFEROUS SERIES	Coal Formation	Upper Coal Measures. Middle Coal Measures. Lower Coal Measures.
			Millstone Grit.
		Carboniferous or Mountain Limestone	Limestone and Shales. Carboniferous Limestone. Calcareous Sandstone.
	DEVONIAN (OLD RED SANDSTONE)	Devonian Beds	Upper Devonian. Middle Devonian. Lower Devonian.
		Silurian, or Upper Silurian	Tilestones. Upper Ludlow Beds. Aymestry Limestones. Lower Ludlow Beds. Wenlock and Woolhope Limestones. Denbigh Grits and Wenlock Shale. Tarannon Shale. Upper Llandovery.
		Cambro, or Lower Silurian	Lower Llandovery. Bala and Caradoc Beds. Llandeilo Beds. Arenig Beds.
	EOZOIC	Cambrian	Tremadoc Slates. Lingula Flags. Harlech and Llanberis Slates and Grits. Longmynd Rocks.
		Laurentian	Fundamental Gneiss of the North West of Scotland and Laurentian Rocks of Canada.

are known to geologists, according to their age, their fossil contents, or the locality in which they have been most studied.

With the exception of the metal iron, more rarely copper, and occasionally one of the noble metals, all the metallic minerals we have to consider are found in the strata from the Permian downwards. The Laurentian, the Cambrian, the Silurian, the Devonian, and the Carboniferous being their great depositories. It follows, therefore, that it is only in those places where these great groups of strata are exposed on the surface of the earth we may expect to find metallic ores and mines.

As a fact these groups of strata make up the great mountain chains of the world; the Laurentian or the Cambrian usually forming the central or basement mass of rock (see figs. 20, 37), and the newer groups reposing in their proper sequence on either side. This arrangement occurs with a remarkable uniformity all the world over.

Further, these great mountain chains will be found, on consulting a map of the world, to have, roughly speaking, a general direction from NE. to SW., sending out spurs and branches in other directions.

Thus, to select the principal examples, starting on the east there is the great mountain chain of the Ural, stretching from the Arctic Ocean on the north to the Caspian Sea on the south, and forming the great mineral depository of Russia. Nearer, there is the range of which the Carpathian Mountains are the southern termination, and which contains the principal mines of Hungary and Transylvania. Then, there is the great group of mountains that starts in Northern Germany and stretches down the promontory of Italy. This in its northern course contains the celebrated mining districts of the Hartz and Erzgebirge.

Next we have the coast line range of Norway, with its many mineral deposits, re-appearing in Bretagne. In our own country there is the Pennine chain, with the lead mines of Northumberland, Durham, York, and Derby. There is also the Western chain, with its ramifications, reaching from the Highlands of Scotland, through the Isle of Man and Wales, to

Cornwall, re-appearing with its rich mineral deposits in the peninsula of Spain and Portugal.

Crossing the Atlantic we find the Appalachian chain of mountains, which, starting in Nova Scotia, runs through the New England States, Pennsylvania and the Carolinas, re-appearing on the southern continent in the eastern metalliferous ranges of Brazil. Then, without noticing for the present the parallel ridges, there is the mighty range and network of the Rocky Mountains, which extend from British Columbia, through California, Utah, Nevada, Arizona, and Mexico, and which in the southern continent is continued in the great ridges and peaks of the Andes. This vast chain of mountains is metalliferous all along its course, and is especially rich in the noble metals. It contains some cf the richest and most marvellous mineral deposits in the world.

Proceeding towards Australia we find the mountain ranges that run down New Zealand and the eastern side of Australia, together with the range on the west coast, of which as yet we know but little. Africa, India, China, and the Malay Archipelago, as far as we know, illustrate the same phenomenon.

It is on these mountains, and in the valleys and ravines by which they are traversed, as well as in the detritus which during long ages have accumulated in the hollows that furrow their sides, and in the plains that stretch along their feet, that we shall find, as we proceed with our inquiries, all the great deposits of metallic minerals in the world.

CHAPTER II.

CLASSIFICATION OF THE DEPOSITS OF METALLIFEROUS MINERALS.

Lodes—Description and Origin—Lodes of Displacement—Gash Veins—Horses—Caunter Lodes—Displacement of Lodes—Dykes—Elvan Courses—Considerations affecting the Dip of Lodes—Earthy Minerals of Lodes—Gossan, Peachy, Caple, Pryan, Quartz, Sparry, Flucan, and Grouan Lodes.

ALL known deposits of metalliferous minerals may be comprised within the following classification :—

1. LODES, comprising or subdivided into	*a.* Simple fissures charged more or less with ores. *b.* Fissures attendant on displacements of strata. *c.* Minor gash veins, terminating in depth.
2. BEDS, comprising or subdivided into	*a.* Stratified mineral deposits. *b.* Irregularly stratified mineral deposits. *c.* Deposits occurring at the place of contact of two dissimilar formations or groups of rocks. *d.* Segregated and crystallised masses of ore. *e.* Flats.
3. IRREGULAR DEPOSITS, comprising or subdivided into	*a.* Pockets. *b.* Contact deposits. *c.* Network of veins. *d.* Disseminated ores.
4. SUPERFICIAL DEPOSITS, comprising or subdivided into	Detrital gold. Stream tin. Bog-iron ore. Cupreous deposits.

1. LODES.

(*a*) *Simple Fissures.*—The word 'lode' seems to be derived from the verb 'to lead,' and so has the same origin as loadstone or guiding stone. A lode in its simple form is a crack or fissure,

which generally extends through the whole series of strata to an unknown depth, as shown in fig. 1, which illustrates the order of strata in the mineral district of Flintshire, North Wales. The lodes pass downwards from the carboniferous limestone into the underlying Silurian strata; but, as seen in the right-hand lode, they usually terminate upwards at the base of the coal measures, which proves them to be of older origin than this formation. The boundaries of a fissure or lode are called 'walls,' or sides, the upper side (*a* fig. 1) being the 'hanging,' and the under side (*b*) being the 'heading' side or wall.

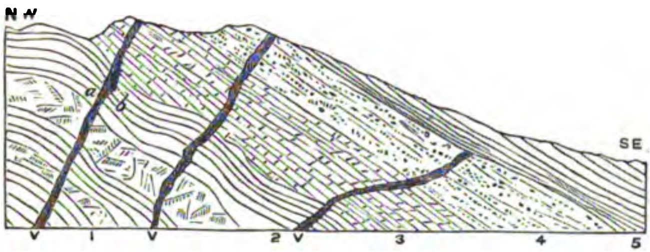


FIG. 1.—LODES IN THE STRATA OF FLINTSHIRE, NORTH WALES.

1, Cambro or Lower Silurian slates, shales and porphyritic rocks. 2, Wenlock shale and Denbigh grits, Upper Silurian. 3, Carboniferous limestone, Devonian being absent. 4, Millstone grit. 5, Coal-measures. *a*, Hanging side of lode. *b*, Heading side of lode. V V V, Veins or lodes.

Fissures of this kind seem to have been produced by the shrinkage of the strata in the process of hardening, or of cooling down from a heated condition, just as the muddy bottom of a pool or the surface of clay land cracks when drying and hardening quickly under a hot sun.

Most fissures that are charged with metallic ores have a general east and west direction, which varies, however, about forty-five degrees on either side. Generally speaking, therefore, their direction is at right angles to the NE.—SW. direction of the great mountain chains just described, and so are found to traverse the strata across, and not along their strike. A vein is a small lode. Lodes dip or incline downwards at all angles from the horizon, and the lode is said to 'hade' in the direction of its dip. This inclination has been affected considerably by

the nature of the strata the lodes have passed through. The 'rents' have been torn at the weakest points. They are usually more perpendicular in hard rock, and sloping in shale, as seen in fig. 14, which illustrates this uneven course of the lodes of Durham and Northumberland. In many cases the strata appear to have been elevated and curved prior to the formation of the fissure, so that while it is the rule that the lode runs through or across the bedding, it not unfrequently happens that the dip of the lode and bedding coincides for some distance, as seen in fig. 2, which generally illustrates the mode of the occurrence of the lodes of the Gongo Soco gold mines, as more particularly described in Chapter VIII.

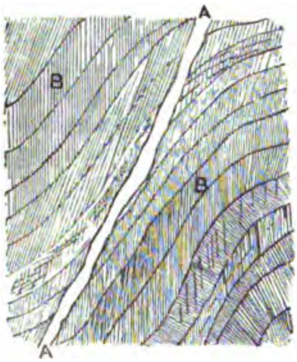


FIG. 2.—SHOWING THE VARIOUS RELATIVE POSITIONS OF LODE AND STRATA.
A A, Lode. B B, Strata.

(*b*) *Fissures of Displacement.*—A lode of the kind just described lies in strata whose bedding is continuous and unbroken; but it often occurs that the beds on each side of the fissure do not correspond to each other, the beds on the lower side occupying a higher position than those on the hanging or upper side of the lode as seen in fig. 3, where the beds are supposed to be thrown up twenty-five feet to the north. The lode C C, therefore, occupies a fissure made during a disturbance of the strata, which has caused a displacement of the beds.

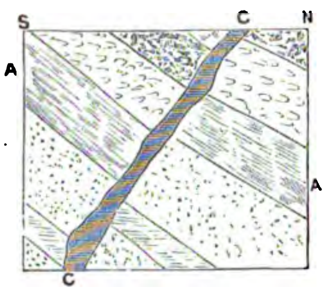


FIG. 3.
A A, Beds displaced by fault.
C C, Line of displacement, forming lode.

Generally speaking, great lines of displacement run north and south. They are of more recent origin than the east and

west fissures, because they have cut through and displaced the latter. They are also, taken as a whole, less metalliferous than the east and west lodes.

(*c*) *Gash Veins.*—These are fissures of greater or less width at the surface, but thinning and dying out in depth, as illustrated in fig. 57, of the Dolly Hide Copper Mine in Maryland, and fig. 63, of a mine in Chili. These gash veins may be either simple surface cracks filled with mineral matter, or fragmentary portions of mineralised strata broken off and thrown up on end. The former kind are known by the vein cutting through or across the beds, the latter by the deposit coinciding with the bedding.

There is a variety of phenomena connected with the class of lodes I have thus far described that it will now be necessary to notice.

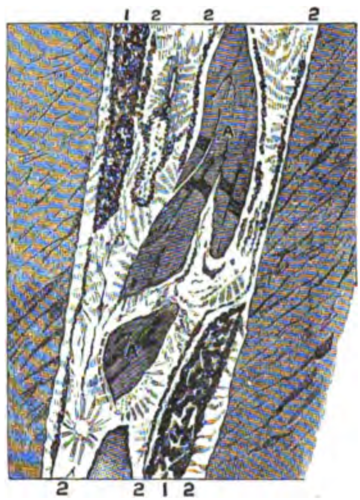


FIG. 4.—SECTION OF LODE AT THE NEUGLUCK MINE, FREIBERG, SHOWING 'HORSES' IN LODE.

1 1, Galena, blende in quartz fragments with iron ores. 2 2, Quartz, calcspar, and other earthy minerals in a breccia. A A, 'Horses' of country rock.

Horses and Branches.—Ofttimes the fissure is not a clean crack from top to bottom, but appears as if the two sides had been torn from each other, and had left shreds and patches of their substance in the midst of the crack. When a large mass of rock is thus left, and the lode is split into two, as shown in fig. 4, the lode is said to 'horse,' the parts of the lode seldom making up between them the full width of the main crack. We can also conceive how, after a crack had been made, portions of the sides would split off, and falling into the fissure make horses and branches. Again, the rent in the strata would not

always be continuous, but the strata in places being more cohesive than at others, there would be a number of minor cracks following the same direction, with portions of strata dividing them, as shown in fig. 4. When these ramifications were numerous, and covered a large space, we should find a mass of rock traversed by a network of veins, forming what the Germans call a stockwerk, like that of Geyer, illustrated in figs. 67 and 68, Chapter XX. In this case a true lode of class i. becomes a member of the irregular deposits, class iii.

Besides the main fissure, there are usually associated with it minor veins, which enter it and cross it at all angles. Where these veins only penetrate the strata on one side, and die out at no great distance, they are nothing more than strings or

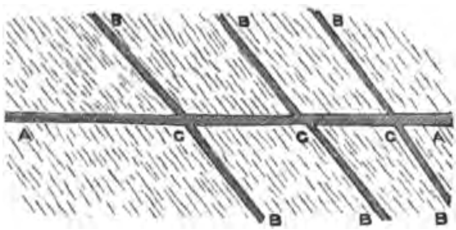


FIG. 5.—'CAUNTER,' OR CONTRA LODES.
A A, Main lode. B B, Caunter lodes. C C, Points of intersection usually rich in ores.

branches. Where they decidedly cross it and form a continuous vein or lode, they are known as 'caunter,' or 'contra' lodes, as explained in fig. 5.

In following a lode it is sometimes suddenly lost, owing to its displacement by a disturbance that has affected the strata since its formation. Fig. 6, which gives a section of the Old Wheal Agnes Tin Mine, in Cornwall, illustrates this. AA are faults which have displaced the lode twice.

Sometimes this displacement is horizontal, instead of vertical, as there shown. Fig. 7 represents a displacement of this kind. A A is the lode, B B is the fault, and from C to C is the amount of displacement.

In both cases, as might be inferred from the direction in

which the thrust has been, and as is always found by experience, the lode may be recovered by turning along the obtuse angle of the fault.

Strata are often traversed at all angles by dykes or bands of harder matter, which seem for the most part to have been

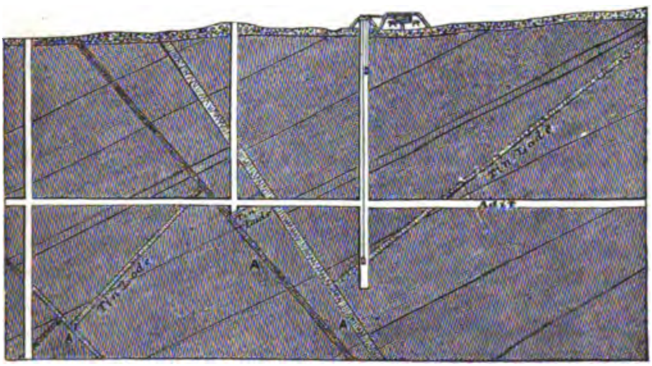


FIG. 6.—SECTION OF STRATA IN THE PARISH OF ST. AGNES, CORNWALL. (Scale: 1″ = 30 fathoms.)

forced up cracks in a molten state from the interior of the earth, although they may have been formed by the precipitation and consolidation of very hard material along cracks and lines of disturbance in a similar manner to the way in which lodes

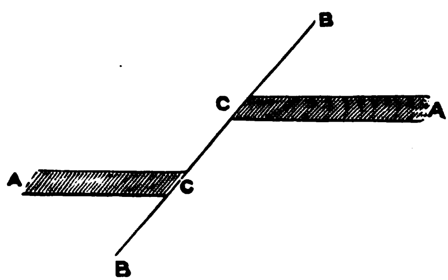


FIG. 7.—HORIZONTAL DISPLACEMENT OF LODE.

have been filled. These are known in Cornwall as elvan courses. Where such dykes are of subsequent origin to the lodes, they cut the latter and displace them in the way already

shown in figs. 6 and 7. Where they are of older date, the lodes are not interrupted, but frequently pinched and contracted. The same effect is produced as the lodes pass through beds of the same material, as seen in the case of the Chanaracillo Silver Mine, Chili, fig. 44, Chapter XIII. This last remark leads to the observation that the strata traversed by a lode are not all of the same mineral nature. There are sandstones, limestones, slates, shales, felspars, granites, and many other varieties of rocks. They consequently differ in compactness, in density, in the power of conducting electricity, and in many other particulars. It is scarcely to be expected, therefore, that the amount of shrinkage and contraction would be the same in each case; and, as a matter of fact, it is not so. A lode usually maintains its average width in ordinary slaty rocks. It narrows, as I have just observed, in its passage through porphyries and greenstones, whether occurring as dykes or beds, and it widens, and becomes more stringy and less well defined as it enters soft shale. Of these and other variations in the width and character of lodes as they pass through different kinds of strata, we shall have many examples as we proceed. The cracks would through all subsequent time form weak lines, or lines of weakest resistance in the strata, and we should expect that in subsequent disturbances of the strata they would sometimes be opened, and space be thus formed for the interposition of fresh matter, mineral or otherwise; and the appearance of the lodes indicates that this has been so.

The fissures I have been describing have during long ages become filled with a variety of minerals. For the most part these are earthy minerals, which partake very largely of the nature of the adjoining rock. Thus, lead lodes in carboniferous strata contain in the millstone grit great quantities of chert and sandstone, and when they enter the limestone, calcareous breccia abounds. In the Cambro-Silurian slates, fragments of slate and re-cemented grains of the same are plentiful. When granite is entered, the lode is charged with its redistributed constituents, especially where the rock is of a decomposing kind.

Further, earthy minerals that enter into the composition of the enclosing strata are found in a selected and separate form in the lodes. Thus, in limestone the lodes are charged with carbonate of lime and fluorspar; in the clayey strata of the Silurian rocks, with baryta; in the harder slaty rocks, that contain a large proportion of silica, quartz largely prevails, as it does also in the harder granites.

According to the prevalence of one or more earthy minerals and the combinations they form with each other, and among metallic minerals, chiefly with iron in lodes, the latter have been distinguished by different names, of which the following are the principal kinds, especially as known in Cornwall, whence a good portion of our mining nomenclature has been derived[1]:—

Gossan Lodes.—Gossan is a cellular friable quartz containing earthy matter, and coloured pale yellow, brown, or black, according to the quantity of iron it contains and the amount of decomposition it has undergone. The amount of decomposition also affects greatly the character of the lode. Black gossan contains the most iron, which often amounts to half the weight of the gossan, and it is hard, solid, and impervious to water. Red is of a hard, crystalline nature. Brown is most decomposed, while both red and brown are more brittle and friable than black. Each of these kinds of gossan bears a special relationship to enclosed metallic ores, as we shall see when we come to consider the metallic contents of lodes. When a fissure is chiefly filled with gossan of any kind, it is known as a 'gossan lode.'

Peachy Lodes.—When chlorite of a greenish colour, with a pearly lustre, and of a somewhat loose and cellular texture, fills up a fissure, it is known as a 'peachy lode.'

Caple or Capel Lodes.—When a lode is largely made up of hard felspar, that passes sometimes into a clayey limestone, it is called a 'capel lode.' Further, in many lodes, especially those which occupy a line of disturbance in the strata, a coating of hardened clay lines either wall, and thus separates the main

[1] W. Pryće, *Mineralogia Cornubiensis*, 1779.

lode stuff from the adjoining strata. These coatings are called the 'capels' of the lode.

Pryan Lodes.—Lodes that are filled with sand and heterogeneous materials, loosely cemented together in a mixture of clay, are called 'pryani lodes,' from *prye*, the Cornish word for clay.

Quartz Lodes.—Fissures filled with hard spar or quartz, are quartz lodes. Quartz occurs in lodes in different conditions. Associated with iron it is grey, brown, yellow, and black in colour, and so approaches a gossany structure. It also occurs in different degrees of density. Now it is compact and solid, filling up the whole of the lode, then it is mixed with other materials; again, it has a loose sugary structure, from which it passes often into a beautifully crystallised form. When these crystals are not large, and stretch and meet across portions of the lode, as seen in figs. 48, 49 and 50, the lode is still further distinguished as 'comby.'

Sparry Lodes.—When a fissure is filled with fluor spar, baryta, or carbonate of lime, or all combined, it is called a 'sparry lode.' As intimated before, lodes of this description prevail mostly in limestones, the others belong chiefly to the older rocks.

Flookan or Flucan Lodes.—When a crack is filled up with stiff glutinous clay, it is known, in Cornwall especially, by this name. As sand and pebbles become mixed with the clay, the flucan passes into a pryani lode. These flucan lodes are usually cross fractures of dislocation, whereby the larger lodes are disturbed, as already described with reference to figs. 5, 6 and 7.

Grouan Lodes.—In passing through granite rocks, fissures, as I have already said, become filled with various-sized fragments of partially decomposed granite. Grouan is a name locally given to granite, hence its application to lodes of this variety.

In this description of the different kinds of lodes, I have enumerated the principal earthy ingredients with which they are filled; and it is in them, as in earthy matrices, that we find distributed, ofttimes with apparent irregularity, but, perhaps, with more regard to order than we usually deem, the ores of the metallic minerals we have further to consider.

CHAPTER III.

METALLIC CONTENTS OF LODES.

Affected by Nature of Strata—Modes of Occurrence—Origin and Derivation—Infiltration—Condensation—Sublimation—Causes affecting the Particular and Local Deposition of.

THE nature of the strata traversed by lodes is found, from long observation, to determine to some extent the kind of metallic ore that predominates in the latter. Of this we shall have many examples in the course of our inquiry; and it will suffice to say here, generally, by way of illustration, that quartz lodes passing through granitic rocks, especially when pyrites are present, are the favourite resorts of gold. In North Wales the hard blue slates of the Llandeilo strata are favourable for the production of lead. Lead is also the prevailing metallic ore in limestone rocks, although there are occasionally deposits of copper. Alternations of greenstone and porphyritic rocks with slates produce copper. Granite, especially the upper, coarse, and partially decomposed granite of Cornwall, is the prolific rock for tin. A lode, therefore, changes in the character of its contained metallic ore; as in Cornwall, a lode passing through bluish 'killas,' or slaty rocks, contains copper, which gives place to tin when the underlying granite is reached. In Shropshire, also, the lodes that are productive of lead ore in the bluish grey slaty rocks of the Llandeilo series, become poor in lead and richer in copper as they pass into the underlying grits of the Cambrian rocks of the Stiper stones and Longmynd.

Metallic ores occur in lodes in a variety of ways, as (1) sprinkled in the midst of solid quartz; (2) filling up as a solid body the whole of the crack; (3) forming nests and pockets

connected by strings; (4) forming a considerable deposit on one side of the lode, and when discontinued on one side commencing on the other; (5) irregularly dotted over the whole width of the lode; (6) in regular layers, which, from the centre of the lode to the sides, answer each to each, and, when space permits, between them, crystallising into their beautiful characteristic forms, as shown in figs. 4, 8, 9, 10, 11, 12, 48, 49, 50; and other figures occurring in the course of this book, which represent actual lodes, will illustrate most of these modes of occurrence. Besides the foregoing, there is an almost infinite diversity of combinations, many of which will come under our notice as we proceed.

FIG. 8.—SECTION OF LODE AT CHRISTBESCHERUNG MINE, NEAR FREIBERG, SHOWING ROUNDED MASSES OF ROCK AND ORE CEMENTED TOGETHER BY CRYSTALLINE, CALCAREOUS, AND QUARTZ SPAR.

At this point, and before I describe the remaining classes of metallic mineral deposits, it will be convenient to ask, and to endeavour to answer the questions, Whence were these metallic minerals originally derived? and by what means did they get into lodes as we now find them?

A great deal has been written on this difficult natural problem from the days of Job until now. Especially has the inquiry been attractive since Werner taught with such power in the Mining School of Freiberg, a hundred years ago. Each author has his favourite explanation, which he usually expounds to the exclusion of all others. The true answer, as I take it,

The mode of the origin and means of the deposition of

metallic minerals are not one only, but many. We should therefore endeavour to assign to each cause, or set of causes, its proper place and degree of influence in the whole range of the causes that have contributed to the final result.[1]

To begin at the beginning, we may safely suppose that the metals, together with all the simple elements we have enumerated, formed part of the original mass of this globe when in a molten state, as is now reasonably inferred, it was first started on its revolving course through space.

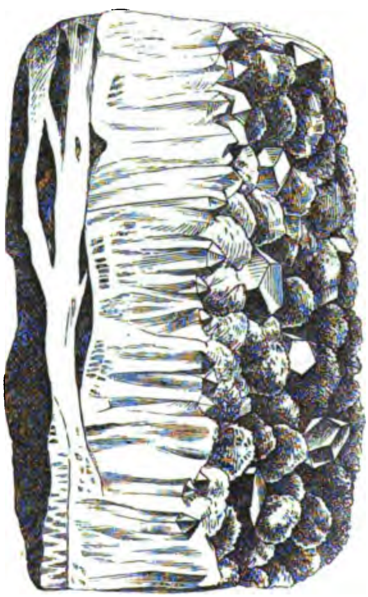


FIG. 9.—SECTION OF A SPARRY LODE NEAR FREIBERG, SHOWING CRYSTALS OF CALCAREOUS SPAR AND QUARTZ, WITH MANGANESE IRON ORES AND LEAD ORES FILLING THE INTERSTICES.

It follows therefore that, as the outer surface of this molten mass cooled and hardened, the metals contained at various points would be enclosed within the outer crust in both collected and disseminated forms. The disseminated metals would be those distributed and quickly fixed through the whole mass. The collected metals would be those which in a fluid or semifluid state gravitated towards cracks, cavities, and shrinkages of the containing rock. Especially would this retention of the metallic constituents near the surface be most complete where the cooling was most rapid; where, on the other hand, the cool-

[1] See Werner's *New Theory of Mineral Veins*; Robert Were Fox, *On Mineral Veins*; De la Beche's *Geology of Cornwall*; Von Cotta, *On Mineral Veins*; Salmon, *On Mineral Veins*; Henwood's *Metalliferous Deposits*, &c.

ing was slow, the metals, by their greater weight, density, and fluid nature, would sink down with the inner molten matter, leaving such parts of the surface barren of metals.

When, in course of time, an atmosphere encircled the earth, and moisture descended in rain and accumulated in hollows on the surface, a wearing-down process began, by which portions of the original crust began to be abraded and washed into watery hollows, there to be deposited in a new form as sedimentary strata. The contained metals would be washed away along with their enclosing rock, and would be disseminated throughout the newly forming strata. They would form deposits in hollows of the sea-bottom, interstratified layers, fill up cracks, and altogether the strata in the neighbourhood of an original metalliferous mass would be highly charged with metallic minerals in various states of combination and form.

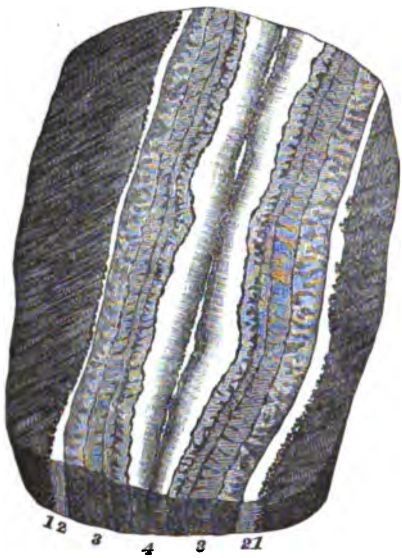


FIG. 10.—SECTION OF THE DREI PRINZEN LODE, NEAR FREIBERG.

: 1, Blende. 2 2, White quartz. 3 3, Layers and crystals of fluorspar and quartz, with spots and clusters of blende. 4 4, Calcareous spar, with cavities in the centre, containing lead ores.

As these sedimentary strata became cracked and fissured by subsequent elevation, drying, and disturbance, the water flowing through them would take up the metallic particles, and, meeting with partial stoppages and interceptions as it passed through cracks and cavities, would deposit its heavy mineral burden on the floors and sides of the same. The power of the

water to dissolve the metals out of the enclosing strata would be assisted by its associated chemical agents—acids, salts, and the like—as well as by the high temperature which it is likely prevailed in the earliest periods of the earth's history. The power of the agents being spent, the temperature cooled by any cause, and the flow of the water interrupted, the mineral matter held in solution would be deposited as we have supposed. Thus, by means of infiltration, we have one, and perhaps the principal, explanation of the deposition of metallic minerals in lodes.

FIG. 11.—SECTION OF LODE AT ALTE HOFFNUNG GOTTES MINE, NEAR FREIBERG, SHOWING FRAGMENTS OF ROCK SURROUNDED BY QUARTZ AND CALCAREOUS SPAR, AND CONTAINING IN THE INTERSTICES, LEAD, BLENDE, MANGANESE, AND IRON ORES.

Further, we may suppose that portions of the water would find their way down cracks to the molten masses lying within the fiery chambers underneath the cooling crust; and how, reascending in vapours mineralised by contact with liquid metals and other molten matter, they would permeate cracks and chambers, penetrating every opening where they could unhindered find their way; and how, condensed by contact with the cooler surfaces of hardened rocks, the contained minerals would be deposited on the surfaces of these as far as the vapours reached; just as mineral matter is deposited and accumulates on the sides of boilers and within steam pipes. Thus in a second way, by means of condensation,

we can conceive how mineral matter may have been deposited in lodes.

Again, we may imagine how, in the intense fusion and combination of molten substances going on amidst the heat of the earth's great laboratory, gases would be driven off and forced upward through every fissure and chink along the course of which the contained metallic matter would be deposited; just as the lead, sulphur, arsenic, and other minerals that escape in fumes from reduction furnaces, are now intercepted and deposited in the long flues and great chimneys of our chief mines and smelting houses; and thus, in a third way, by sublimation, we see how the earth's cracks may have become lined and charged with metalliferous ores.

FIG. 12.—SECTION OF LODE AT THE ALTES HOFFNUNG GOTTES MINE, NEAR FREIBERG, SHOWING QUARTZ AND MICACEOUS SLATE IN PARALLEL LAYERS.

The precise places and methods of the deposition of metallic ores, thus brought generally from above and below, would depend upon a variety of causes. It would be determined in the first place by the direction of the cracks ready to be filled. I have said that the most productive lodes run roughly from east to west. They are evidently the oldest cracks, inasmuch as the north and south cracks cut them through and disturb them. The great work of charging the lodes with metallic matter seems to have been partly completed before the north and south fissures were made. This east and west direction of the older cracks may have re-

sulted from the tendency there is, when a strain is applied to substances, to break across rather than along their length. Then this east and west direction seems, in connection with electricity,[1] to have had an influence on the deposition of metallic matter in these lodes. The water filling the fissures, heated from below, and charged with mineral matter, would be ordinarily a better conductor of electricity than would the adjacent rocks. Currents of electricity would, if not otherwise controlled, pass along it to the west. These currents would assist in decomposing the mineral salts, earthy or metallic, and lead to the negative pole or rock. The deposit would further be influenced by the composition of the rock traversed, which, according to its enclosed minerals or temperature, would be electro-negative in one place, and electro-positive in another. The regularity of the deposition would also be interfered with by a variety of circumstances—the evolution of sulphuretted hydrogen by some, the absorption of oxygen by others, and the solidifying of the minerals. Thus the flow of the currents would be interfered with.

We can also readily see that the quiescence or otherwise of the water would affect the deposit. Where the water was intercepted and lay quiet, as in cracks in hard rock closed up above and below by shale and mud, the deposition of mineral matter would be most perfect; just as it is in quiet pools and precipitation tanks, rather than in running streams, that solid matter is deposited from water now.

Referring again to the three methods by which we have seen how fissures may have been filled with metallic minerals, I may further observe that, generally speaking, it is among the lodes that traverse the oldest granitic, gneissic, and metamorphic rocks of the Laurentian and Cambrian groups that we find indications of the two latter modes of origin; while it is in the clay slates of the Cambro-Silurian and Devonian, and in the Carboniferous Limestone, that we find abundant examples of the first method.

Thus, in Yorkshire and Derbyshire, it is when passing through the synclinal troughs or hollows formed by the limestone beds that the lodes are most productive of metallic ore.

[1] Robert Were Fox, *On Mineral Veins.*

Such lodes as are filled with breccia and drifted materials, in which are lumps and aggregated masses of ore, are doubtless due to infiltration. Solid metallic lodes—where the ore is very pure and, filling the whole chasm, is hardly separable from the walls of the lode—seem to point to a sublimated origin. Where, again, the metallic matter occurs in parallel layers, the result may have been occasioned by gradual condensation from ascending vapours. Where, however, such layers are loose in texture, and the enclosing mineral coarse, the result may have arisen from infiltration.

Probably in the same lode, each of the modes of operation may have been employed, in its turn contributing its quota to the final result.

CHAPTER IV.

SECOND, THIRD, AND FOURTH CLASSES OF MINERAL DEPOSITS.

Stratified Mineral Deposits—Irregularly Stratified Deposits—Contact Deposits—Segregated and Crystalline Masses of Ore—Flats—Irregular Deposits—Pockets—Contact Deposits—Network of Veins—Disseminated Ores—Superficial Deposits.

I NOW proceed to notice the second great group or class of mineral deposits, and begin with those that are regularly stratified.

II. BEDS.

(*a*) *Stratified Mineral Deposits.*—Metallic ore deposits, especially those of iron and copper, frequently occur as beds ordinarily interstratified with other beds. Of these, we have examples in the ironstone layers of the coal measures; the ironstone beds of Missouri (fig. 114), the copper deposits of Anglesea (figs. 53,54 and 55), the copper deposits of the New Red Sandstone, and the ironstone seams of the Jurassic strata, fig. 113. Of course all stratified beds contain a larger or a smaller amount of metallic matter, especially iron, those we are now considering differing from the ordinary beds in the greater amount of metallic matter with which they are impregnated, and which renders it profitable to work them.

A stratified bed may have become charged with metallic matter in several ways. For example, (1) the water in which it was laid down may have been supplied with the mineral it held in solution, to be precipitated on its bed, from vents and communications with the earth's interior, as for example, by mineral

springs, or submarine volcanoes. It would thus derive its supply, first hand, from the original source. Or (2) the mineral may have been brought into the water by streams flowing into it from rocks already impregnated with it; just as on the coast of Peru and Chili the sea contains so large a proportion of silver brought down from the mountains as to plate the copper sheathing of vessels remaining in its waters.

Such a process would be more intense in some regions than in others; and at such points the deposits forming on the sea floor would be most strongly charged, the mineral matter lessening its quantity as it receded from the centre of action.

(*b*) *Irregularly Stratified Mineral Deposits.*—The regular or irregular stratification of such a deposit would depend upon the pre-existing contour of the sea bottom, the action of tides and currents; and it would also be affected by the different specific gravity of the substances thrown down upon it.

When land was depressed below the sea level, its surface would present all the inequalities which had been made upon it by abrasion and disturbance. It would have escarpments and valleys, hollows and protuberances; and the effect of the first matter deposited upon it would be to fill up the hollows. Moreover, the heavy metallic constituents would sink to the lowest points, and would thus form irregularly stratified deposits.

(*c*) *Contact Deposits.*—Such deposits would make one form of contact deposits, or deposits lying between two dissimilar 'formations' which would follow the undulations of the surface of the older strata.

(*d*) *Segregated and Crystallised Masses of Ore.*—Again, in shallow seas, a process of jigging and buddling would be going on on a large scale, in which, by means of tides, storms, winds, and currents, the lighter earthy matter would be carried away, leaving the heavier metallic particles in coalescing masses behind. To this mechanical action we must add the chemical processes, dependent upon the liking or affinity which one metal has for another, resulting in the readiness with which some

coalesce, and the force with which others repel. Thus on a large scale the processes of precipitation, segregation, and rough crystallisation would go on which we see exemplified in smaller chemical experiments within our own laboratories. These lenticular, wedge, and irregularly shaped mineral masses would in their turn be covered over by earthy matter; and if we think of the subsequent process by which the strata in which they are enclosed have been upheaved, hardened, and tilted at all angles, we have imagined the probable history of deposits like the iron ore deposits of Norway (fig. 108), the zinc ore deposits of Belgium (fig. 104), and of others described in this book.

(*e*) *Flats.*—Flats are of three principal kinds. 1. There are the flats that occur in the limestones of the North of England, described in Chapter XXV. There are long stretches of alternating shales and limestones, the latter of a sandy and readily decomposing kind, that contain irregularly shaped deposits of ore extending horizontally to a great distance, but limited in depth to certain beds. They are portions of the limestone mineralised (see figs. 93 and 94). Flats are also of another kind. Recurring to the phenomenon of shrinkage, which, as we have seen, is irregular according to the texture of the strata, we find that, in strata composed of limestones alternating with shales, the cracks in the former are intercepted by the latter, and are not always continued in the lower limestones immediately under those of the upper. We find the crack passing down the shale along the dip of the beds, and starting downwards through the underlying limestone, where the power of resistance has been weakest, as seen in fig. 13.

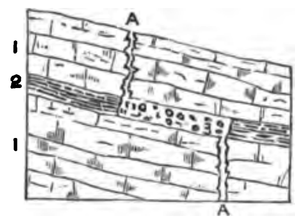


FIG. 13.—ILLUSTRATION OF CRACK FOLLOWING LINE OF WEAKEST RESISTANCE.

1 1, Limestone. 2, Shales. 3, Flat charged with ores. A A, Fissure or lodes.

A good illustration of the way in which a crack becomes more horizontal and usually less productive as it passes through

intervening strata beds, is seen in fig. 14, adapted from Wallace, which is a section of a lode on Alston Moor, in the North of England.

Usually a good part of the shale bed has been washed away, and its place has been taken by clay, in which are imbedded

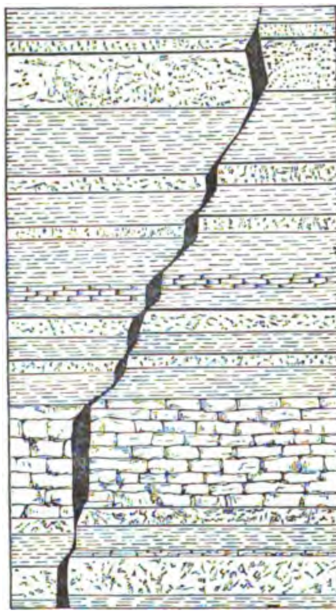


FIG. 14.—SECTION OF LODE AT ALSTON MOOR, SHOWING CHANGES OF DIP AND PRODUCTIVENESS OF DEPOSIT.
Thick perpendicular parts most productive.

almost pure lumps of galena, which have been washed from the lodes above and the overlying limestones. A third kind of flat has been occasioned by a sinking or subsidence of the lower portion of a series of limestone beds leaving an irregular crack partly horizontal which has subsequently filled with earthy earthy minerals and metallic ores. Fig. 97, Chapter XXVI., is a representation of such a flat as it occurs at the North Hendre Lead Mine, in Flintshire.

III. Irregular Deposits.

I will begin the description of this class of deposits with—

(*a*) *Pockets.*—Pockets, bonanzas, vughs, or cavities, filled with ore, are of frequent occurrence, especially in limestone strata. Of this kind of deposits we may take the hæmatite deposits of the Forest of Dean (fig. 110, Chapter XXIX.), and the silver lead ore deposits of the Eureka and Richmond Mines, in Nevada (fig. 41, Chapter XII.).

Pockets like those of the Forest of Dean may have been formed at the time of the deposition of the strata, in the manner just described; for we have only to suppose that in a given stratum segregations of metallic ore took place, and the insterstices filled up with ordinary calcareous mud, to see how pockets that occur along the line of bedding in unbroken strata may have been formed.

But pockets have at times no reference to the stratification; they are not found lying in one or more beds along the direction of their bedding, but crossing the stratification somewhat irregularly, as is the case with the Nevada pockets (fig. 41, Chapter XII.). This kind of pocket is usually found in limestone strata. Now in all such strata may be seen, wherever they are quarried, great irregular patches of what is known among quarrymen as 'rotten rock.' This is rock from which lime is largely absent. It consists often of loose, friable sandstone. Where such a deposit lies, as is often the case, under a crack communicating with the surface, with one leading out below, the result is the washing away of the whole friable mass, and ordinarily the formation of a cavern in its place. This cavern, like a fissure or lode, is now ready to have deposited within it the minerals held in solution by the water passing through it. The deposition of mineral matter will go on fastest when the flow of the water is most checked. Where the flow is swift and continuous, a cavern alone remains, like those common in the Carboniferous limestones of Wales and York-

shire; but in the former case a pocket or bonanza, charged with metallic and other minerals, is the result.

(*b*) *Contact Deposits.*—(*c*) *Network of Veins.*—(*d*) *Disseminated Ores.*—Among the older strata we have many examples in eruptive rocks how, at times, from pressure applied elsewhere, portions of molten matter have been forced up from the interior of the earth, and have overflown the surfaces of the strata they have burst through.

Now the intense heat attendant on such eruptions would have, and indeed has had, great effect upon the adjacent strata. It has hardened them, changed their character—in the language of science, metamorphosed them.

We may easily imagine how any metallic substances they contained would be melted, would fall down as far as they could, filling up every crevice they could find, and would often at last nestle in hollows at the point of contact with the underlying eruptive mass, in some cases penetrating that mass itself. In this, therefore, we find another explanation of the origin of *contact deposits.*

The eruptive mass would also be itself charged with whatever metals prevailed in it as it lay quiescent in the furnace below. In the process of cooling, especially if this were slow, this heavy metallic matter would sink to the bottom of the overflowing mass and gravitate towards hollows in the underlying rock. This affords us an illustration of the way in which a contact deposit lying underneath an eruptive rock may have been produced.

The metallic matter would also fill up cracks and gaps of shrinkage in the underlying strata, and thus form in another way *network of veins* like that of Geyer (figs. 67 and 68, Chapter XX.), already referred to, as well as *gash veins* that die out in depth, as in figs. 63 and 79.

Again, if the process of cooling were quick, as under some conditions, especially near the surface, it would be the metallic matter that would be retained in the eruptive mass. This retention might either be in fine particles diffused, as grains of gold and of tin occur in granitic rocks, or if the cooling were not very

rapid, in minute cracks threading the whole mass as the result of shrinkage, producing once more the phenomena of the stockwerk of Geyer just referred to.

A study of the volcanic phenomena observable at the present day, together with that of geysers and mineral springs generally, will serve to illustrate much of what I have been supposing, and help to elucidate this difficult subject in its varied and extensive bearings.

IV. Superficial Deposits.

In the drift and other loose matter that covers the more solid framework of the globe, we find important metallic deposits, especially those of gold and tin. We shall have occasion to notice these more in detail, so that it will not be necessary here to do more than say that they lie along the base of the mountains whose strata contain the deposits from which they have been derived. The mode of their occurrence in beds, continuous or otherwise, will afford us additional explanation of the way in which the older stratified beds of metallic ore, regular or irregular, were originally formed.

I do not know that I have exhausted my list of all the possible ways in which the various deposits of metallic minerals may have been produced; but the illustrations and examples I have given will afford the student the clue to the explanation of the whole phenomena, and will help him to work out in further detail the theories as they affect the class and species of deposit in which he is most interested.

We may, therefore, now pass on to consider in detail each metallic mineral separately, together with the conditions under which it it is found in various parts of the world.

CHAPTER V.

GOLD.

Characteristics and Modes of Occurrence—Driftal Gold—Nuggets—Gold in Lodes and Veins—Alluvial Deposits of the Ural Mountains—Mining in the Solid Rock—Austro-Hungary—Mines of the Banat—Gold in Central Europe—Sands of the Rhine—Lodes and Alluvium of France, Spain and Portugal, and Italy.

GOLD does not often occur in nature in a mineralised form, but is usually found in its native or metallic state. It is, however, frequently alloyed with copper, silver, and other metals. Rarely, as in Transylvania, it is found mineralised by association with tellurium.

In form it occurs as cubes, mostly small, which are often distorted and elongated. Also in grains and plates, in hair-like fibres, and in dendritic or tree-like incrustations.

Its hardness ranges from 2·5 to 3·0. The colour is yellow of various shades; the lighter colours of which are due to the presence of silver in large quantities. Its specific gravity is very great, ranging from 12·666 to 19·079, varying according to the metals alloyed with it, the purest gold being the heaviest.

From its resemblance in colour to iron pyrites, the latter substance is often mistaken for gold. One easy test of the difference between the two lies in the great ductility and malleability of gold as compared with iron pyrites. It will flatten under a blow, whereas pyrites will crush to powder.

Indeed, one of the most noticeable qualities of gold is its extreme malleability; a grain of it may be made to cover a space of $54\frac{3}{4}$ square inches, and it may be beaten into leaves the $\frac{1}{280000}$ of an inch thick.

When perfectly pure, gold is called in commerce gold of 24

carats, or fine gold. If it is alloyed with two parts of silver, or one part of silver and one of copper, or the like equivalent of other metals, it is said to be 22 carats fine. So, if it contains only 20 parts of pure gold it is 20 carats fine.

The two following analyses of gold will illustrate two extremely different conditions of alloy and of specific gravity :—

1. Gold from Russia.
Specific gravity, 19·099.

Gold	98·96
Silver	0·16
Copper	0·35
Iron	0·05
	99·52

2. Gold from Marato.
Specific gravity, 12·666.

Gold	73·45
Silver	26·48
	99·93

General Modes of the Occurrence of Gold.—Gold is found in two widely different conditions. First, it is found distributed in gravel, sand, clay, and other detrital matters that cover the valleys and plains which furrow the sides and extend along the base of great mountain chains. This condition, although the newest presented in nature, is probably the oldest in which gold seems to have been known to mankind. Probably all the gold of ancient times was derived from such sources; the earliest explorers having been attracted by its rich, shining, yellow appearance, as it glistened in the river sands.

The drift containing gold has, of course, been produced by the whole array of abrading causes—the atmosphere, rain, rivers, sea, and ice—all of which have helped in their turn, and with various combinations of effort, to disintegrate and displace the solid rocks, and to spread their ruins over the valleys and plains.

Probably the peculiar disposition of the gold in the drifts of any one locality has been affected by the prevalence or greater activity of one or more of these agents over the rest.

Gold occurs in these drifts in fragments and grains of all sizes. The larger lumps are known as nuggets, and some of these have been found of a large size. The largest known was found in California, and weighed 134 lbs. 7 ozs. Another weighing 96 lbs. was found near Miask, in the Ural Mountains,

and is now in the Museum of the Imperial School of Mines at St. Petersburg. Another of 27½ lbs. weight was also found in California.

Dr. Genth[1] suggests that the gold of the larger nuggets was originally disseminated as fine grains throughout the parent rock, from which it was dissolved and washed out, to be again segregated or collected into lumps and masses of irregular and often fantastic shape in the waters of the driftal seas. I may observe as a digression that he applies partly the same theory to gold found in veins; inasmuch as he has found the native bismuth from the peaks of Sorato, in Bolivia, interlaminated with gold, and the ore bed in the metamorphic slates at Springfield, America, to consist in its upper part of magnetite, in its lower of copper pyrites and other ores, and interlaminated with these films of native gold. To return, as washings, diggings, placer, and hydraulic mines, these drifted deposits have been worked for gold from the earliest times until now.

Secondly, gold is found in lodes and veins, chiefly filled with quartz, that traverse the older slaty and metamorphic rocks, principally those of Cambrian and Laurentian age, as well as finely disseminated in rocks of a granular structure. This form, although the oldest mode of occurrence in nature, is the one more recently known to men, and still more recently worked with success. Excepting some of the Brazilian mines, and one of doubtful success in the Ural Mountains, there was, only forty years ago, scarcely a gold mine profitably worked in the solid rock.

The explorers for gold in drifted matter have gradually followed the object of their search up the mountain sides, until they have struck in veins and lodes some of the sources whence the alluvial gold has been derived.

The diagram (fig. 15) which represents the structure of the Ural Mountains, to be noticed presently, will illustrate the relation borne by these two classes of deposits to each other. The size of the quartz veins is necessarily exaggerated.

[1] *American Journal of Science and Art*, September 1859.

With these general prefatory remarks I will proceed to notice the chief gold producing districts of the world, beginning in the east with the

URAL MOUNTAINS.—The Ural or Oural Mountains extend from the Arctic Ocean to the Caspian Sea,[1] a distance of 1,000 miles from north to south. Along their course they form the natural boundary between Europe and Asia. A few of the highest peaks reach an altitude of 5,000 feet, but the greater number do not exceed 2,000 feet.

Referring to the section, fig. 15, the groups of strata, 1, 2,

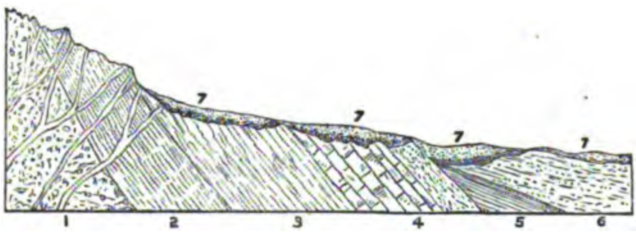


FIG. 15.—SECTION SHOWING THE TWO CONDITIONS UNDER WHICH GOLD IS USUALLY FOUND.

1, Granitic and gneissic rocks, often containing gold finely disseminated. 2, Micaceous, talcose, and argillaceous slaty rocks, Laurentian and Cambrian. } Traversed by quartz veins containing gold.
3, Silurian and Devonian strata. 4, Carboniferous limestone and grits. 5, Coal measures. 6, Permian and newer rocks. 7777, Drift filling hollows in rocks, with gold, especially at the base of the drift.

and the lower part of 3, are penetrated with greenstones and porphyritic rocks, often in a crystallised and mineralised form. The gold is frequently found disseminated in these intrusive and imbedded rocks, as well as in the quartz veins that traverse them, and the groups 1 and 2 enclosing them. The stratification is the same on both sides of the chain, and on the eastern, or Siberian side, gold is visible to the naked eye in the slaty rocks 3. It is probable that gold will be found in greater or less quantities all along the range, but at present the gold-producing region is almost limited to the country lying between the 51st and 56th degrees of N. latitude, with the

[1] *Geology of Russia in Europe and the Ural Mountains.* (Murchison and Verneuil.)

town of Ekaterinburg in the centre. The entire gold-producing country of Russia is, however, estimated by M. Boglubski[1] at 2,000,000 square miles. Unless others have been started recently, the only underground mines are those at Berezoosk, near Ekaterinburg, on the Siberian side of the mountains. It was here that mining operations were first commenced on the first discovery of the gold in 1723. The rock here is decomposed granite, containing numerous veins of quartz, in which the gold is scattered. Shallow shafts are sunk in the rock, and levels driven into the veins, and the production of these underground mines, from the year 1725 to that of 1841, was estimated at 30,000 lbs. troy of gold. In 1850 the yield was 100 lbs. The analysis of the gold of these mines stands thus—

Gold	09·280
Silver	00·702
Copper	00·006
Iron	00·008
Loss	00·004
	10 000

Attempts at mining in the solid rock were made up to the year 1823 in sixty-six other localities, but these were all abandoned; for thus far the Russians have found it easier to obtain gold by digging and washing the drift lying in the higher valleys and hollows of the mountains, and the low-lying land stretching eastward into Siberia. The drift seems to be of the same age as our glacial drift, bones of recent and recently extinct animals being found in its uppermost layers. Gold is most plentiful in it where the drift is most largely charged with iron. Fig. 16, adapted from Murchison and Verneuil, is a section of the drift at the Sormanosk mines, near Miask, the shaded portions, just overlying the upturned and eroded edges of the underlying strata, showing the auriferous portion of it.

The gold washings of the Ural are of recent date. The few there are on the western side were established by the

[1] *Gold and Gold Mining in Russia.*

Government in 1829, and those of the eastern in 1838. The proportion of gold obtained is from 65 to 120 grains to 4,000 lbs. of the enclosing drift, the annual production per man being $1\frac{1}{3}$ lbs. in the private works, and $1\frac{3}{4}$ lbs. in the Government works.

Whitney,[1] writing in 1854, described the production of these

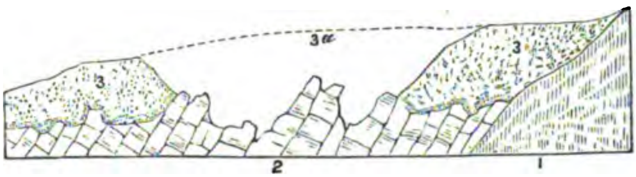


Fig. 16.—Section of Gold Diggings south of Miask, Ural Mountains.

1, Granitic and gneissic rocks. 2, Crystalline limestone. 3, Auriferous drift. 3a, Drift removed.

Russian gold fields as having reached its maximum in 1847, and as steadily declining, and likely to decline. The result has been better than he anticipated. The entire gold production of Russia last year being 66,956 lbs. against 42,000 lbs. in 1842.

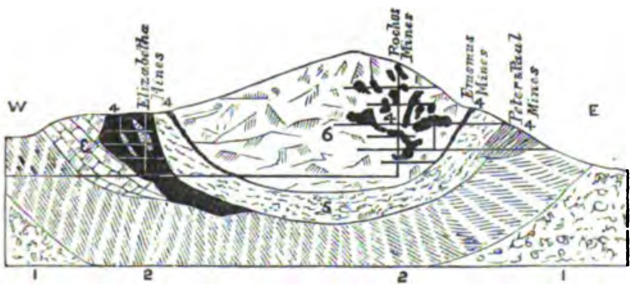


Fig. 17.—Section through the Oravicsa Group of Mines SW. Hungary.

1, Granitic and syenitic rocks. 2, Crystallised slates, becoming calcareous as at 3. 4 4 4 4, Mineralised deposits. 5, Gneissoze rock, with garnets. 6. Felspathic and porphyritic rocks.

The exceptionally good year was 1847, with a production of 75,000 lbs.

Austro-Hungary.—Gold has been mined in Hungary since

[1] *Metallic Wealth of the United States.*

the eighth century, and extensive remains of ancient workings still remain. Mines cluster around the towns of Schemnitz, Kremnitz, and Neusohl in Lower Hungary; the Amalia mine near Schemnitz being now worked for gold at a depth of 600 yards. The mode in which gold occurs with other minerals will be illustrated by fig. 17, which is a section through the Oravicsa group of mines[1] in Lower Hungary, closely adjoining Transylvania. The deposit at the Elisabetha Golgotha mines fills up a cavity in quartzose and calcareous rocks. The earthy part of the deposit consists of fragments of limestone, some of which are of large size and are rounded by aqueous action. These, with quartz fragments cemented together in a clayey matrix, fill the middle part of the cavity 4. In this gangue, gold is found in separate grains, and also associated with pyrites. A layer of tough clay two to three feet wide is sprinkled with thick threads and grains of gold which are associated with auriferous pyrites. Small veins of quartz and calcite containing gold in these different conditions also penetrate to some depth the underlying calcareous rock. It is from the disintegration of such as these, probably, that the metallic deposits are derived. The quartz veins are often worth 100*l.* per fathom. The pyrites in the main deposits are not very plentiful, but they contain from 6 to 10 oz. of gold per ton, and rich lumps of gold are attached to the boulders of the deposit. In the clayey band gold is associated with rare and interesting minerals, as glaucodote, alloclase, bismuth glance, specular iron, and cobalt blume. In the central breccia these minerals give place to mundic, lead, and antimony. The proportion of silver to the gold is one-eleventh. The associated auriferous mundic is sold at from 7*l.* to 10*l.* per ton, and the bismuth at 22*s.* per lb. The gold is sometimes closely associated with tellurium, and mineralised by it.

CENTRAL EUROPE.—Although no productive gold mines, either hydraulic or underground, are worked in connection with the older rocks that form the central axes of the mountainous

[1] See also *Mining Journal*, 1878, p. 140, *et seq.*

network of Germany and Bohemia, yet these strata must contain an appreciable quantity of the metal, inasmuch as the sands and mud of the rivers Danube, Rhine, and Rhone contain small proportions of gold.

Those of the Rhine are, or were recently, worked between Bale and Mannheim, gold to the value of 2,500*l.* being extracted yearly. The sands worked near Strasburg are estimated to contain 30 parts of gold in 100,000,000. Occasionally the proportion reaches double this amount. If it were not for the cheapness of labour, gold in such minute quantities could not be profitably extracted. The wages of the Rhine gold-washer are usually not more than 10*d.* a day, sometimes they reach 1*s.* 8*d.*, but never exceed 2*s.* He usually treats 11¼ tons of sand per day.

France.—In France some of the lead lodes contain minute quantities of gold. An auriferous quartz vein, the only one known, occurs in the older rocks at Lagardette, in Isère, department of the Basses-Alpes; and the alluvium of the neighbouring rivers are reported to contain gold; but none has been obtained in recent years.

Spain and Portugal.—These countries are said to have yielded considerable quantities of gold in ancient times. In the time of Pliny, Galicia and the Asturias were considered the richest gold fields known, yielding 20,000 lbs. annually. Recently operations have been confined to washings on the rivers Sil and Salor, the produce of which is estimated at about 2,000*l.* per year. With the influx of English enterprise and capital, this branch of mining industry in Spain may, under safe government, revive.

Italy.—Gold was mined in Italy in ancient times. It is still obtained at the Pestarena mines near Valanzas. The lodes which traverse the older rocks consist of white quartz that contain iron pyrites, lead, and blende. When carefully selected the lode stuff contains from 9 to 13 dwts. of gold.

CHAPTER VI.

GOLD—continued.

Gold deposits of Gogofau—The Dolgelly District—Scotland—Ireland—*In situ* and in Alluvial Deposits in County Wicklow.

BRITAIN.—In very minute quantities gold is present in the sea-sand and river detritus that occur on the western shores of the island, where the older rocks form the rugged surface. It follows, therefore, that these older rocks must contain some proportion of gold *in situ.* There are the remains of a mine at Gogofau, west of Llandovery, in South Wales, where the Romans worked a gold mine in large quartz veins, that traverse slaty strata of Arenig or Upper Cambrian age. There are yet visible the stones and troughs they used for crushing the vein stuff, and traces of the aqueduct by which the water was conveyed for washing. The veinstone still shows on analysis minute quantities of gold diffused throughout it.[1]

The most important gold region of Britain lies on the north side of the estuary of the river Mawddach, in Merionethshire,[2] and it occupies both sides of that river as it bends from Dolgelly towards the hills about Trawsfynydd. There are traces of old Roman and it may be British mines; but in recent times the region was found to be auriferous, about the year 1844, by Mr. Arthur Dean, who, on examining the ore and débris heaps of the Cwmeisen lead mines, found fragments of ore that contained as much as 7 oz. of fine gold to the ton.

[1] Sir R. I. Murchison, *Siluria.*

[2] Ramsay, *Geology of North Wales;* Dean, *British Association Reports,* 1844; Calvert, *Gold Rocks of Great Britain and Ireland;* J. A. Phillips, *Gold Mining and Assaying.*

This discovery lead Mr. Dean to examine the whole of the Duffws range of mountains, when he found that many of the quartz veins and lead and copper lodes of the district were impregnated with gold. Trials were made by local explorers, among whom were Messrs. Parry and Williams, who, after many failures and much trouble, succeeded in making the discovery of gold at the Vigra and Clogau copper mine, from whence they obtained gold to the value of 36,000*l.* The importance of this discovery (in 1854) was, however, greatly overestimated, A mania for gold mining set in. Companies were formed with quite the full complement of chairmen, directors, secretaries, engineers, managers, and assayers; costly machinery was procured and conveyed at great cost to this hilly region, then destitute of railways. The result was disappointment, and the traveller may see, as I often have seen, in the remains of massive and costly machinery stranded on the hillside, traces of the fatal collapse of the gold fever. Even the mines which had yielded enough of gold to remunerate the native economical workers collapsed utterly under the more elaborate and costly direction. It may be well to place on record the names of a few of the mines that were started. Among them were Berthllwyd, Cwmeisen, Cwmeisen Issa, Dolfrwynog, North Dolfrwynog, Gwynfynydd, Tyddyn Gwladys, and the Vigra and Clogau, where the great discovery was made. This mine is now the only one at work. In 1875 it produced 548 ozs. of gold, of the value of 2,005*l.* 17*s.* 6*d.* In 1879 the production was 447 ozs. 10 dwts. 15 grns.

The strata in which the auriferous lodes occur belong to the junction of the Lower and Upper Cambrian strata, where the Lingula flags of the latter rest upon the uppermost grits and quartzites of the former group. They consist of talcose and steatitic slates, which decompose at the surface to an unctuous clay. Iron and copper pyrites are disseminated throughout the rock, and there are numerous minute copper veins.

The lodes of the district may be grouped into three classes: 1. Quartz veins containing ores of silver, copper, and more rarely lead and blende; these have a direction NW. and SE.,

and dip to the north. 2. Veins filled with carbonate and sulphate of barytes, with lead and blende, but seldom copper; these are NE. and SW. veins, dipping south. 3. Auriferous veins, which trend due E. and W., and dip to the north. In width they range from a mere thread to six inches, and rarely opening out to two or three yards. These veins pass through the other mineral lodes, and it is at the points of intersection that gold is found most plentifully in the quartz veins.

It there occurs in grains, which often enclose a minute grain of quartz; in thin films upon spar, and where the quartz is cellular filling with other minerals the minute cavities. The second group of veins are the poorest in gold, even at the points of intersection. It is in the crossing of the groups 1 and 3 that the metal has most accumulated.

At the Vigra and Clogau mine, the gold is obtained, or was when I examined it in 1865, from irregularly branching veins of quartz, which are sprinkled with iron and copper pyrites. The gold was then mostly visible to the naked eye, and distinguishable from the pyrites by its deeper yellow colour. At various points where the veins cluster together, the gold was most abundant, and these richer points were connected by veins and strings of quartz barren of gold. In 1875 1,216 lbs. of selected quartz from such points yielded 73½ ozs. of gold.

At Cwmeisen mines an assay of oxides of iron showed 18 dwts. 3 grns. of gold to the ton of ore. Another assay gave of lead 67 ozs., silver, 10 oz. 5 dwts. 8 grns., and of gold 1 oz. 15 dwts.

At Gwynfynydd mines the lodes were quartz, containing minute specks of gold sometimes visible to the naked eye. They held also gold-coloured mica, containing a little of the metal, and the gold was distributed alternately upon the hanging and the heading sides of the lode.

At Dolfrwynog the chief gold-bearing lode was quartz, with a branch of sulphate of baryta running through it. On each side of the barytes was a seam of lead, which in places gave as much as from 50 to 60 oz. of gold to the ton.

At Berthllwyd blende ore was found, in which the contained gold ranged from 1 to 60 ozs. per ton, with a fair proportion of silver.

The Welsn gold was all of a pale colour, owing to the presence of silver. Specimens obtained by Mr. Readwin from Gwynfynydd were 18 carats fine, one from the bed of the river Cain was 18 carats fine, and a crystal of gold picked up to the west of the south end of Bala Lake was only 14 carats fine. The present value of the gold derived from the Clogau mine is about 3*l.* 18*s.* per oz.

It remains to be seen whether, with strict economy and with the use of the most approved appliances for mining and dressing the ores, these North Wales gold mines can yet be made to pay. In a report of the Clogau mine, issued in 1875, it was stated that the yield of the rough ores was from 7 to 8 dwts. per ton. If this quantity could be depended upon for any considerable length of the lodes the mine should be profitably worked. From one of the rich clusters of veins before alluded to, 9,310 tons of ore gave 12,416 ozs. of gold, 22 carats fine, or nearly 1¼ oz. to the ton. The following analyses of two samples, by the late Mr. David Forbes, will show the character of the gold from this mine :

Gold	90·16	89·83
Silver	09·26	09·24
Copper and Iron . .	trace	trace
Quartz	00·32	00·74
Loss	00·26	00·19
	100·00	100·00

SCOTLAND.—Gold has been found in Scotland to some little extent, in strata similar to those just described. The men of the mining district of Leadhills, in Lanarkshire, have occasionally employed their leisure time in searching for the metal among the alluvial deposits and mine débris of the district. Gold is also found in the drift of Sutherland, and it has been traced up the valleys to a great body of metamorphic rocks, which are pierced by intrusive granites.

IRELAND.[1]—Gold is found *in situ* in county Wicklow, where it is sprinkled throughout the sulphur course referred to in Chapter XVII. and shown in fig. 56. The proportion is greatest in the decomposed or gossany upper portion of the course. Two analyses gave respectively 7 dwts. 12 grns. and 17 dwts. 12 grns. Subsequent analyses have given a smaller result. The returns from this source for the year 1878 only amounted to 5 oz. 3 dwts. 17 grns.

Detrital gold was discovered in the same county in the year 1796, in the Balinvalley brook, a tributary of the Ovaca river. In the autumn of that year hundreds of people were engaged in digging and searching for gold. In about six weeks from the time of the discovery the Government took possession of the place and guarded it with soldiers. Under the direction of some local gentlemen of mining repute, systematic operations were conducted, with little profit, until 1798, when the works were destroyed in the rebellion of that year. The works were resumed in 1801, and further explorations were made in the neighbourhood. Various attempts have since been made by private adventurers and mining companies, but these have from time to time been abandoned.

The gold seems to have been derived from the ferruginous quartz ridges that traverse the granitic and gneissoze rocks that form the bases of the mountain range, and also from deposits like the sulphur course described in Chapter XVII. The gold lay dispersed through a layer of gravel and clay, which was covered with from 20 to 50 feet of superficial drift. With the gold was associated magnetic ironstone, copper and iron pyrites, and oxide of manganese. The gold occurred in grains and nuggets, from the most minute in size up to a nugget weighing 22 ozs. Analyses of the gold gave of gold 92·32, silver 6·17, and of iron 0·78.

It is estimated that the peasantry during their six weeks' work obtained 800 ozs. the Government, from 1796 to 1802, 944 ozs., and the Carysfoot Mining Company, from 1857 to 1862, 85 ozs.

[1] W. W. Smyth, *Mines of Wicklow; Records of the School of Mines*, vol. i.; Weaver, *Trans. Geol. Society*, vol. v.

CHAPTER VII.

GOLD—continued.

Eastern North America—New England States—Virginia—Nova Scotia—New Brunswick—Lake Superior—California and the Western States—Alluvial Deposits—Gold-bearing Strata—Statistics.

EASTERN AMERICA.—The eastern slopes of the Appalachian mountains appear to be among the oldest gold-producing countries of the North American Continent. Gold washings seem to have been carried on in very early times by the Indians in the Nacooche Valley, Georgia, where an Indian mining village was found by some modern miners buried nine feet below the

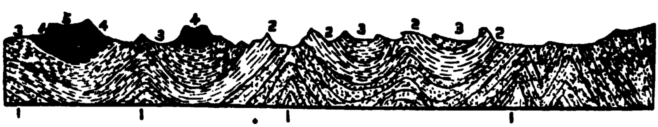


FIG. 18.—IDEAL SECTION ACROSS THE APPALACHIAN CHAIN.

1 1 1, Cambro-Silurian, consisting in Canada of Potsdam sandstone, Trenton limestone, Utica slate, and Hudson River group. 2 2 2, Silurian (in Canada, Gaspè limestone, &c.). 3 3 3, Devonian. 4 4 4, Lower Carboniferous rocks and sands. 5, Coal-fields.

surface of the ground. There were thirty-eight low timber houses, all in a row, with their foundations laid in golden gravel, and relics of rude mining appliances lay about. When first found the land was covered with a rich undergrowth of timber. The sources of the gold in this eastern region lie in the base ment strata of the Appalachian and Alleghany chain of mountains, which, starting in the dominion of Canada and ramifying through Nova Scotia, run down the New England States, Virginia, the Carolinas, to Alabama and the Gulf of Mexico.

Fig. 18 will convey an idea of the general structure of these mountains as they pass through Pennsylvania.

In fig. 19 we have the intimate structure of the older rocks about the gold mines in Virginia; and the diagram may be taken as a sufficient illustration of the condition under which gold is found all along the range from Canada and Nova Scotia on the north to Georgia on the south.[1]

In Virginia gold is worked in syenitic and slaty rocks, into the composition of which the usual materials—chlorite, felspar, mica, silex, and talc—enter with varying proportions. Quartzose beds, that alternate with the slates and veins of quartz, traverse the whole series. These quartz beds and veins are cellular in structure, are readily broken, and contain water. They are frequently tinged with the red and brown oxides of iron, and contain copper and iron pyrites. Throughout this mineralised quartz the gold is scattered in small bunches and separate grains. It is also sparsely sprinkled throughout the slaty beds.

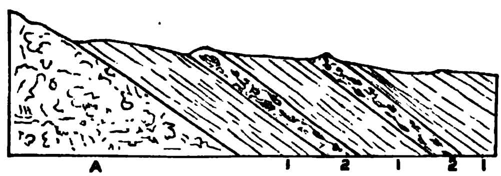


FIG. 19.—SECTION OF STRATA AT WOODVILLE, VIRGINIA.

The veins are nearly perpendicular. Their direction is from NW. to SE., and they are often of large size. They are more regular and continuous in the syenitic rocks. The gold from the slaty portion of the lodes is more flaky than from the syenite. The quantity of gold contained in the productive quartz varies in value from 25*s.* to 20*l.* per ton.

Near Woodville the interbedded quartz takes the form shown in fig. 19: A is the basement, granite, and gneiss; 1 1 1 are thin beds of buff and yellow-coloured talcose slate; 2 2 are auriferous beds consisting of quartz and slate, with much brown ore, and some iron pyrites. The gold is most plentiful

[1] See Whitney, *Metallic Wealth of the United States;* Henwood, *Metalliferous Deposits;* Morton, *Engineering and Mining Journal of New York*, vol. xxv. p. 182.

in the brown ore and in the joints and cavities of the bed. As in Brazil,[1] the gold is most plentiful when the iron ore and quartz are combined, and most scarce where either is alone.

The usual proportion of gold from these beds is 6 dwts. to the ton of ore, and there is some silver in addition. As a rule where the gold is most abundant in these beds it is poorest in quality. Traces of galena are sometimes found.

There are alluvial works on the lower lands, and in Louisa County successful operations have at various times been carried on, during which nuggets varying in weight from one to several ounces have been found.

Southward, both alluvial and underground mining for gold have been carried on in the counties of Cabarris, Lincoln, and Mecklenberg, North Carolina; and in Union, Lancaster, and Chesterfield districts, South Carolina; also in Georgia.

NOVA SCOTIA.—Passing along the mountain chain and its spurs north and north-eastward, a few words will be necessary respecting the increasingly important gold districts of Nova Scotia, New Brunswick, and Lake Superior. In Nova Scotia the Rev. David Honeyman found gold in the year 1861, at the junction of the Truro and Halifax railways. It occurred in chloritic schists of Upper Cambrian age that contained auriferous quartz veins. In 1863 the yield of gold had increased 14,001 ozs. The production of this region in 1877 was 8,200 ozs., much of which was, from the alluvial deposits, derived from the denudation of the auriferous strata.

In central NEW BRUNSWICK gold is found in river valleys, derived as in other cases from the quartz veins that intersect the rocks of the district.

Far away to the NW., on the northern shore of LAKE SUPERIOR, about Thunder Bay,[2] similar strata to those of Nova Scotia are interstratified with Trappean beds, similar to the gold-bearing rocks of North Wales. Veins bearing gold traverse these from E. to W., in which free gold is disseminated

[1] See Chapter VIII.

[2] Nicholson, *Quarterly Journal Geological Society*.

in copper pyrites, with occasionally galena, silver glance, metallic silver, and iron pyrites.

CALIFORNIA AND THE WESTERN STATES OF AMERICA.—From the western side of the Appalachian Mountains the older strata bearing gold dip under the secondary rocks that underlie the great plains of Central North America. They protrude in minor ridges here and there, and at last finally emerge amidst the grand scenery of the Rocky Mountains. This mountain chain, consisting of its great central ridge of the Sierra Nevada, with the parallel ridges of Utah on the east, and the coast range of California on the west, starts, as I have said, far away to the north, in British Columbia, and courses down the western side of the North American continent to Mexico and the south.

It was on the western side of the coast, or Californian range of mountains, on the American Fork, near its junction with the Sacramento, that gold was found in the drift of the river valleys and plains in the year 1848. A saw mill had been erected by Colonel Sutter, a retired officer, and on the first rush of water through the newly-formed millrace, an accumulation of shining yellow particles became apparent, which were soon recognised by Mr. Marshall, the owner of the soil, as gold. Although the attempt was made to keep the matter a secret, by the beginning of July San Francisco was emptied of its inhabitants, and on the arrival of Colonel Mason, the then Governor of California, on the spot, he found four thousand gold diggers and washers at work, who were supposed to be earning 7,000*l.* or 8,000*l.* per day.

The tide of immigration flowed rapidly during the early part of 1849. By July 15,000 Mexicans and Chilians were supposed to be on the ground, and by the close of the year it was computed that 45,000 Americans and 5,000 foreigners were working at the diggings. And the yield of gold for the year 1850 was estimated at 10,000,000*l.*

The present magnitude of alluvial gold mining in California may be inferred from the statement that in 1873 there were 775 mining ditches situated in twenty-five counties. The

ditches were of an aggregate length of 4,863 miles, along which water flowed daily to the extent of 300,000,000 cubic feet. It is supposed that of the gold contained in the drift of that date, three-fifths were secured. In the early days of excitement and prosperity a very large proportion ran to waste, so that the Chinese settlers following here, as elsewhere, in the wake of the Europeans, made a living out of the leavings of the latter. The total yield of gold from California for 1877 was $15,000,000.

After the discovery of gold at Sutter's Mill, the drift of Feather River, another tributary of the Sacramento, eighteen miles to the north, was found to be auriferous in its higher reaches. Stream after stream was searched and found to flow over golden sands.

The drift was, of course, also followed into the neighbouring territories, Lower California, Nevada, Colorado, Arizona, and New Mexico, and in each country finally traced to its source in the mountains.

From the accidental discovery of gold in the millrace at Sutter's Mill, only thirty years ago, has sprung gold mining operations the magnitude of which may be estimated by the returns lately given for the year 1877 of the production of gold in the Western States of America.[1] These are as follows :

Arizona	$350,000
California	15,000,000
Colorado	3,500,000
Montana	3,550,000
Nevada	18,000,000
	$40,400,000,

or about ten million pounds sterling.

As might be expected from the same geological conditions, both as to the stratification of the mountains and the composition of the drift, continuing northwards into BRITISH COLUMBIA, similar results have been attained there. The yield of gold from that country last year was $1,000,000, and at the present

[1] *Engineering and Mining Journal of New York*, January 1878.

time the excitement of new discoveries and the flow of gold-seekers thither is very great.

The gold-bearing drift[1] stretches westward from the flanks of the Sierra Nevada, a distance of about sixty miles. It is, of course, made up of the detritus of the great mountains on the east. Its thickness varies considerably. On exposed surfaces and ledges of rock it consists of a few pebbles only, but it accumulates in the hollows and flats lying between the higher ridges of strata, as represented in fig. 20, to a depth of from six feet to several hundred feet. Its usual composition in such places is on the surface a reddish loam mixed with small gravel. Underneath this is a bed of rolled boulders, some of which weigh from two to three tons. These boulders rest upon a bed of gravel, that fills up the inequalities of the basement rock, and it is throughout this lower gravel that the gold is diffused. The whole series of the drift is often capped by a hard conglomerate set in clay, which has helped to preserve the deposits from denudation. There are also, both underlying the present river channels and sometimes hidden altogether under the drift, old river beds of great size and depth. These when struck and found to be auriferous are called 'leads.' The largest known of these, and one which may be taken as an example of the rest, is the Big Blue Lead. It has been traced from NW. in Sierra County, SE. to Forest Hill in Placer County, California, a distance of sixty-five miles. Its depth ranges from one to three hundred feet. Gold is distributed throughout the whole of this drift, which contains a preponderance of quartz boulders, some of which near the bottom of the old river bed weigh twenty tons. The particles of gold are found of larger size, and contain more silver, at the bottom than the top of this ancient drift, and are worth less by about *2s. 6d.* per ounce. It is supposed that this difference in quality is caused by the larger size of the fragments below resisting more effectually the action of sulphuric acid, which, set free by the

[1] *Mining Statistics West of the Rocky Mountains*, Raymond, 1870; Whitney, *Metallic Wealth of the United States; English Mining Journal*, 1877.

decomposition of pyrites, has eaten the silver out of the smaller grains at the top of the deposit.

The quantity of gold in this lowest drift varies a good deal. At the top of the drift of the Big Blue Lead just described, the proportion varies in value from *2s.* to *8s.* per cubic yard, but many places near the base have yielded *10l.* to the cubic yard, or leaving out the big boulders, to two or three cubic feet. Gold to the amount of *2s.* per bushel of dirt is also a common estimated quantity in the higher hollows of the mountains, and the following are some recent particulars of less rich deposits in California :

In Nevada County, 275 cubic yards of drift gave gold equal to 7½*d.* per cubic yard.

Another claim in the same county, from 16,000,000 cubic yards of drift, gave 15*d.* to the cubic yard.

In Placer County 43,000,000 cubic yards in the Gold Run district gave 2⅝*d.* per cubic yard, and in Yuber County 25,000,000 cubic yards from Smartsville gave 12½*d.* per cubic yard.

The gold is ordinarily found in thin scales and minute grains, also in plates and lumps, and occasionally, especially high up the valleys, in lumps weighing many pounds. Each particular locality, however, presents its own variety of gold, in colour, size, and shapes of the grains.

Recently the shore sands of California, and the western coast generally, often black in colour, have been proved to be auriferous, and efforts are now directed towards the profitable extraction of the gold from them.

This description of the auriferous driftal deposit of California will be generally applicable to the like deposits northward into British Columbia, and southward into Mexico.

The whole of these vast deposits of detrital gold are traceable, as in all the other instances given, to the quartz veins and lodes that intersect the strata of the lofty mountains, and to the grains of gold that are disseminated throughout the granitic rocks that lie at the base of the series. The region is so vast, and was so recently an unknown country to white men, that

although the United States Government has its scientific exploring parties constantly at work, we have as yet but few detailed sections of the strata of these mountain ranges. The section, fig. 20, shows the general geological structure of the region, and it will help us when we come to speak of silver to define the metalliferous zones of strata.

The strata that look so orderly in the section have been upheaved, tossed, and sculptured into the grandest, wildest, and most fantastical forms. There are conical peaks 12,000 to 14,000 feet high—great north and south ridges, now terraced, and again strewn with cyclopean ruins. Winding through these ridges, and cutting perpendicular walls 3,000 feet high, are great ravines or cañons, which debouch as valleys in the open plain. Between these ravines the strata are often worn and fretted

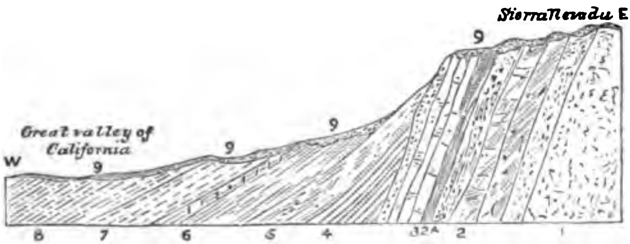


FIG. 20.—GENERAL SECTION FROM THE SIERRA NEVADA INTO CALIFORNIA.

away, so as only to leave pillars and buttresses, *buttes*, pointing towards the sky. Snow mantles around the higher peaks and terraces during the winter, taxing, together with the fierce play of the winds, the ingenuity and energy of the miner, who even up there is burrowing and delving, if not to become rich, at least that he may live.

Turning now more particularly to the section, fig. 20: 1 represents the central granitic and gneissic rocks of the mountain chain. They are probably of Lower Cambrian age. The granite is often coarse, and easily decomposed. 2 shows the overlying slates and sandstones. The slates have undergone a good deal of change and hardening, which has destroyed any fossil remains they may have contained. They are crystalline,

and are both interbedded and intersected by porphyritic and serpentine rocks. They make on the surface a series of ridges parallel to the main axis of the great chain. They and the underlying rocks are traversed almost all along their strike by numerous quartz lodes, or ledges, as they are locally called, from their width, and from the fact that they stand above the edges of the surrounding strata. This is the case where the quartz is free from the oxides and sulphides of iron, and is consequently white in colour, and compact and hard in texture. Where these iron ores are present the quartz is coloured red, and the upper portion of the lodes is decomposed. Lodes of the latter character occur more frequently in some of the more inland and southern States. Throughout these lodes gold is unequally distributed. 2A consists of a vast series of crystalline and metamorphic rocks, green, grey, purple, and blue slates, gneiss and gneissic rocks, which over large areas are changed into quartzite of an almost uniform texture of a bright and clean grey colour. This series has been proved to be the equivalent of the Potsdam sandstone, which is in its turn the equivalent of our Lingula and Tremadoc beds, or Upper Cambrian group of strata. It follows and flanks on either side the central range from British Columbia to Mexico, forming a belt on the western side of more or less continuity, and of a very great width. Everywhere throughout this vast extent of country gold is sparingly disseminated throughout the entire mass.[1] At several great centres of disturbance, as at Mount Lincoln in Colorado, Bald Mountain in Montana, in Western Oregon, and in Northern California, it abounds in gash veins that contain the purest kinds of gold. 3 consists in the lower part of Devonian, and in the upper part of Carboniferous limestones, with their interstratified shales and sandstones. With the exception of iron ores, they form the uppermost limit of the metal-bearing strata of the region, and, as we shall see, contain on the eastern side of the chain the great silver-bearing deposits of Nevada and Utah. Gold does, however, occur in the newer

[1] See also *Engineering and Mining Journal of New York*, December 8, 1877, p. 144.

strata partly in contact deposits and partly in driftal and re-deposited materials derived from the older strata. 4 are the Coal-measures, for the most part overlapped by the Triassic rocks, 5; but recently workable coal seams have been found in the hollows and plains of Colorado, which is a matter of the first importance for this mining region, especially as the hillsides are cleared of timber. 6 are the Oolitic, 7 the Liassic, and 8 the Tertiary group of strata. Overlying the whole of these groups are the driftal deposits, 9, containing the redeposited gold. Good mining results have thus far been attained to a depth of 1,900 feet. The highest hydraulic and underground mines of this region, and indeed in the world, are those of the Little Annie and Summit Rio Grande, County Colorado. The former are 11,000, and the latter 12,000 feet above the sea. There are only about 110 days when any outdoor work, save felling timber, is possible, and during three years July has been the only month in which snow did not fall. The annual snow fall is 24 feet. The latter mine is, notwithstanding its height, successfully worked, the quartz yielding gold to the value of 6*l.* per ton. Ordinarily the proportion of gold is less than this amount. I have before me the statistics from seven ordinarily paying gold mines in California, the average production of gold to the ton of quartz from which is 2*l.* 10*s.*

The total amount of gold produced by the United States from 1848 to the close of 1874 was 250,000,000*l.*, of which about three-fourths were produced by California alone. A continuous yield of three-eighths to half an ounce of gold to the ton of quartz is considered equal to profitable working.

CHAPTER VIII.

GOLD—continued.

Central America—Venezuela—Brazil—History of Gold Mining in Brazil—Mines of Gongo Soco and St. John del Rey—Analysis—Other Countries of South America.

CENTRAL AMERICA.—In proceeding southward, to describe the important gold mines of Brazil, I may notice in passing that gold was discovered in Nicaragua in 1850. It was worked in a rude manner until 1864, when an examination of the country was made by Mr. W. C. Paull. Shortly afterwards the Chontales mines were established, further south. Here, as in the region just described, gold is found in quartz veins that traverse metamorphic rocks.

VENEZUELA.—In Venezuelan Guiana, gold was discovered by Dr. Passard in the bed of the Yururari River, in 1849, and this place has been supposed to be the El Dorado of Sir Walter Raleigh. Doubtless, as these Central States and Northern States of the South American continent become more settled in their government, mining enterprise will develop. Gold, along with silver, is already being worked to a limited extent by an English company in Venezuela. Let us now pass on to

BRAZIL.—This is one of the oldest, as it is still one of the most important, of gold-producing countries. Gold mining operations are chiefly conducted in the province known as the Minaes Geraes. This district lies in the southern part of the country, and is situated between the two great ranges of mountains that run in a south-westerly direction from the north-east corner of Brazil. The district is about one hundred miles in length, having the towns of Villa Rica and St. John del Rey,

with the mines that cluster around them, in the south, and the mines of Gongo Soco in the north, the distance between the two groups of mines being about eighty miles.[1]

Gold was known to exist in the south of this region in the year 1543, when the Indians made their fish-hooks and personal ornaments from it. The first white man that found it was Antonio Rodrigo, who discovered it on the banks of the Riveao, a small stream that falls into the larger river since known as the Rio des Mortes, near the towns of St. Jose and St. John del Rey. Rodrigo, dying shortly afterwards, was followed by his son, and he by the Paulistas, or people of St. Paul's, to which district he belonged. The Paulistas, fighting over their booty, killed each other in considerable numbers, and so gave the name of River of Death to the stream on whose banks they fought.

The banks of this stream soon became furrowed and burrowed by rude attempts at surface mining, and the quality of the gold obtained from this spot was long considered the finest in Brazil. North of the town of St. John del Rey is that of Villa Rica, which owes its name to the amount of gold obtained in its vicinity. The Paulistas here found gold that darkened in colour on exposure, owing to its alloy with silver. They called the mountain Ouro Preto, but on great quantities of gold being obtained they changed the name of the town that had sprung up to Villa Rica, the rich town. It was owing to the daring of the Paulistas that the discovery of gold was followed up and the district colonised.

For a long time the gold was only extracted from the clay, through which the rains from the mountains had filtered, leaving behind the particles of heavier metal. The first mines were thus simple pits, called 'catas.' These were worked downwards until the gravel, or 'cascalho,' below, cemented together with the oxides of iron, was reached. This was broken by picks, and taken to the river to be washed. A step in advance, and one that anticipated the modern method of hydraulic mining,

[1] See also Mawe's *Travels in Brasil*; Henwood's *Metalliferous Deposits*; 'Reports of St. John del Rey Mines,' *Mining Journal*, 1877–8.

was to bring the water to the gravel, and thus wash the gold on the spot, instead of carrying the gravel to the water. These works were called 'lavras.' Following this gold-bearing drift upwards, it was traced at last to the outcrop of the great lodes of ferruginous quartz, whence it had originally been derived. These, for some depth below their outcrop on the hillsides, were decomposed, and were readily worked by open trenches cut into them.

Beyond this, native skill and enterprise could not go; indeed, the wonder is how, with their primitive appliances and little knowledge, so much gold was raised. Gradually the attention of English and German miners was attracted to the country; by slow degrees concessions were obtained from the Government, surveys were made, and operations of a true mining nature were commenced by the sinking of shafts and by the erection of a rude stamping machine made of wood. It was to work a concession on the Morro Velho estate that the English company, known as the St. John del Rey Company, was formed in the year 1830. The mines of this company have been successfully worked until the present time. This property was bought of the original adventurers, in 1725, for less than 20*l.* In 1814 it yielded 43½ lbs. of gold; last year its production was about 4,500 lbs.

It will help us the better to understand the position of the lodes worked here if we first consider the geological structure of the country, as this is illustrated further north at the mines of Gongo Soco, six miles SE. of Caethe. These mines were discovered by a solitary Portuguese, named Manuel Camara, who worked the gold deposit with his own hands, and became rich. The thought occurred to one of his successors that he was only working the refuse of an untouched body of gold, so he searched the mountain beyond, and was rewarded by the discovery of gold spread through a lode or bed forty feet wide. This discovery led to levels and shafts. The success that attended his efforts attracted more scientific and systematic miners, who, in the year 1825, took the name of the Imperial Brazilian Mining Association. I do not know the present com-

mercial condition of these mines, but I observe that they are attracting attention.

Fig. 21 will illustrate the geological position of these mines, as well as that of the lodes of St. John del Rey.

At the base, as in North America, we have the usual granitic and gneissose rocks, 1. These are succeeded by a series of clay slates, 2, which often become micaceous, talcose, and chloritic. These slates contain great masses of quartz veins, and they are interbedded with thick quartzose flagstones. Above these there is a deposit of granular calcareous quartz, 3, in which are thin beds of talc and mica, that occasionally give place to ferruginous ores. These expand occasionally into

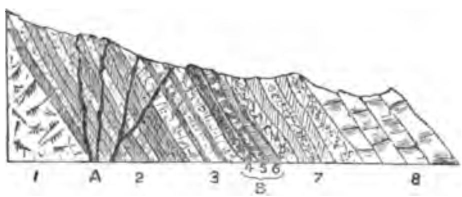


FIG. 21.—SECTION NEAR GONGO SOCO, BRAZIL.

1. Granite and gneiss. 2, Micaceous clay slate, with beds of massive quartz. 3, Calcareous granula quartz, with thin beds of talcose slate. 4, Itabirite. 5, Jacotinga. 6, Canga. B, Gongo Soco auriferous deposit. 7, Slates and porphyries. 8, Dolomitic limestones. A, Place of St. John del Rey lodes.

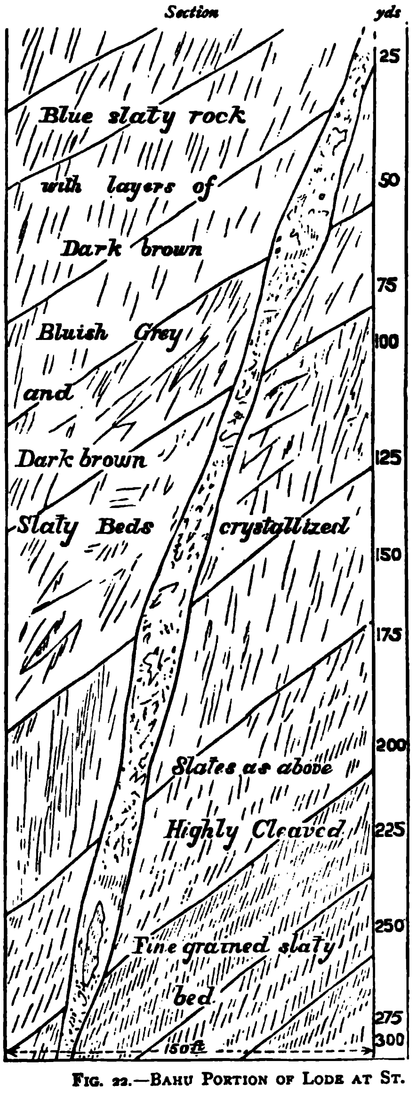
thick ore deposits, of which 4, 5, and 6 are examples; and which, as they form the auriferous deposits, will require a more detailed description. This metallic zone is overlaid by the massive hornblendic slaty and porphyritic rocks, 7, which are succeeded by dolomitic limestones, 8, in which magnesia is present to the extent of 35 per cent.

Gold is disseminated throughout the entire series. In the granitic rocks it is associated with palladium, and it appears in a crystalline form in the cavities. It also occurs abundantly in the veins A that traverse the slates, as at St. John del Rey, especially as they cross the quartzose beds; but here at Gongo Soco the beds 4, 5, and 6, now to be described, form its great depositories. 4 is known as Itabirite; it is from 1 foot to 6 feet thick. It consists of iron disseminated in mica slate. It

also contains distinct quartz masses, and where these occur it contains the most gold. 5 is a bed called Jacotinga, from its resemblance in the variety of its colours to the Brazilian bird of that name. It is here composed of iron glance, earthy brown iron ore, brown manganese, flakes of talc, and layers of manganese. Its thickness varies from 6 feet to 30 feet, but several beds of the nature of those above and below, are occasionally interstratified with it. It forms the chief repository of the gold, which is spread in crystals and particles throughout the entire bed. It is most abundant where the manganese is present, when it occurs in bunches and strings, the bunches seeming to succeed each other along and down the bed at an angle of 45 degrees to the north-west. Crystals of very fine yellow gold are found near the surface. This bed is overlaid by the 'Canga,' 6, which is a brecciated calcareous deposit, containing blocks of specular and oxidised iron ores, cemented by earthy iron ore. The Canga does not contain gold in profitable quantities although it is on record that in the year 1826–7 nearly 4,000 lbs. of gold were taken from it. The whole of the deposit formed by these three beds is of great thickness near the surface, but it thins downwards, so that at a depth of 70 fathoms from the surface it is only 8 fathoms thick. Partaking, as it does, of the nature of irregular bedding, it may again thicken in depth and probably increase in hardness.

Returning now southward, the deposit worked at Morro Velho is a true fissure vein. It occupies the position of the lodes at A, fig. 21. It is divided into two principal parts—the Bahu and Cachoeira. These again have branches, one of which is known as Gamba, and another as the Quebra Panaella. The lode has a general east and west direction, and so far has been most productive on the eastern half of its course through the property.

Fig. 22 represents a section of the strata and of the structure of the lode down to a depth of about 300 yards. From this section it will be seen that for nearly half of this depth the lode is constituted chiefly of quartz, but that in the lower half more slate enters into its composition. The inclination of the



Nature of Lode.

Mixture of slate and quartz.
Ditto, with iron and copper pyrites, quartz crystals, and spathose iron.

Massive quartz, with bars of slate and crystals of arragonite.

Quartz iron pyrites and spots of copper.
Cavity with spathose iron.

Large masses of iron pyrites.
Lode as above; 235 grains of gold per ton of ore.

Lode traversed by bar of slate.
A horse of slate, with carbonate of iron and arsenical pyrites in vein.

350 grains of gold per ton.
400 grains of gold per ton.

FIG. 22.—BAHU PORTION OF LODE AT ST. JOHN DEL REY MINE.

lode and its branches is varied by the bedding of the strata. Sometimes the lode follows the course of the bedding for some distance at their strikes down a joint; at such points it is richer than usual in gold. Near the surface the sides of the lode are ragged, the jagged edges of the adjoining rock projecting into it, but in depth the sides become more even. When undivided the lode is about 14 yards wide, but its width varies, as shown in fig. 22. In a branch lode running parallel with the Bahu, from 150 to 200 grains of gold per ton of lode stuff were obtained within 40 yards of the surface. In the Cachoeira part, at from 200 to 220 yards, 218 grains to the ton were extracted. In the Quebra Panaella, 130 grains were obtained at a depth of from 150 to 160 yards. On the whole, the lode does not deteriorate in depth, although there are points where it is not so productive; for experience shows that a mixture of iron pyrites and quartz makes the best matrix for gold: the metal being abundant where they are pretty equally mixed, but scarce where either prevails separately. Since this description was written, the report of this mine for the year 1877–8 has been issued, and the following extract from the superintendent's portion of that report will afford an idea of the present condition of this remarkable lode:—'As the lode was laid open on April 1 last (1878), it may be described as being divided into five parts, differing more or less from each other, in length, figure, and component matter. The first, beginning on the eastern extremities and extending westward to nearly one-third of its entire length, is composed mostly of pure ore, but has for the greater part of its length a strip of quartz on its north side and of killas slate rock on the south. The *next*, or second division, forming approximately another third of the length, is composed almost entirely of killas, with numerous shoots of ore striking across the slate rock. Following this on the west, in the third division is found a mass of pure ore of about a ninth the entire length of the lode, with a strip of quartz on the north side. In the fourth division we come to a mass of quartz of about the same length, with shoots of ore striking across it, and then in the fifth divi-

sion, at the extreme west, pure ore as far as excavated on each side.'[1]

The production in the shallow workings years ago was about seven-eighths of an ounce per ton, and this was the rate of production last year. The estimated yield for the present year is about 55,000 ounces.

A full analysis of the gold from this mine gave the following results:

Gold	07·499
Silver	01·793
Lead	00·180
Bismuth	00·035
Copper	00·045
Antimony	00·030
Arsenic	00·105
Iron	00·195
Mercury and loss	00·018
	10·000

The quality at different depths has been: from surface to 100 yards, 18 carats; 100 to 200 yards, 19 carats; 200 to 284 yards, 19 carats. The gold obtained from Gongo Soco mines has averaged 19 carats; from Ouro Preto, 22 carats and of dark colour; and from Antonia Pereira, $23\frac{7}{8}$ carats fine. The total production of gold in Brazil at the present time may be estimated at 100,000 ounces.

Of the other countries of South America it may be summarily stated that their joint production of gold about equals that of Brazil. In Chili, on the west of the Andes, we find gold mining rising in importance. At the mines of Catapillo the dressing of the refuse ores left by the Spaniards has yielded from 3*l.* to 4*l.* worth of fine gold per ton of refuse. The production of Buenos Ayres for the year 1875 was 4,000 ounces. Increased attention is being paid to this metal in Peru, and the mines of Arequipa are said to yield 4 ounces of gold to the cajon of ore. The mountains in which the gold mines are worked on the western side of the continent are a continuation of those of California, Nevada, and the North-Western States, and their geological structure is similar.

[1] *Mining Journal*, June 29, 1878, p. 723.

CHAPTER IX.

GOLD—continued.

Australasia—History of the Discovery of Gold—New South Wales—Victoria—Tasmania—Queensland—Productiveness of Reefs in Depth—Structure of Reefs—Gold Drifts—Proportion of Gold in Drifts.

AUSTRALASIA.[1]—We will now cross the Pacific Ocean to the gold mining regions of Australasia.

New South Wales.—Count Strzelecki is said to have been the first to find gold in New South Wales, in the year 1839; but in deference to the wishes of the then governor, Sir G. Gipps, the discovery was kept secret, the colony being then a penal one. In 1841 the Rev. W. Clarke had also found the metal. In 1847 Mr. Clarke called the attention of the colonists to the auriferous character of the country, and from that date to 1850 he personally explored the larger portion of the gold-bearing lands, over six degrees of latitude, from Queensland on the north to the Australian Alps of Strzelecki on the south, where from the high ridges of Mount Kosciusko, 6,500 feet high, the land dips south into the province of Victoria.

In 1848 a survey of the country was undertaken by the Government, at the suggestion of the late Sir R. I. Murchison. In 1851 the value of the diggings was proved by Mr. Hargreaves. The localities in which detrital gold was first found to any workable extent were on Summerhill Creek and the Lewis Pond River, in lat. 33° N., long. 149° 15′ E., in streams that run from the northern flank of the Corioboalas down to the river Macquarie, a river that flows northward and west-

[1] See also R. Brough Smyth, *Gold Fields of Victoria; The Yearly Colonial Mining Report;* Murchison, *Siluria;* J. A. Phillips, *Gold and Gold Mining.*

ward The metal was afterwards found on the Turon river that rises in the Blue Mountains. Discoveries continued to be made until, stretching north into Queensland and south into Victoria, a region 1,000 miles long from north to south was proved to contain gold in its driftal deposits. The growth of gold mining enterprise in New South Wales will be judged from the fact that in 1876 the total production of gold was 167,412 ounces, of the value of 613,190*l.* 7*s.* 9*d.* In 1875 the yield had been 50,698 ounces more. Following close upon the discovery of gold in this colony, was its discovery in the more southern province of VICTORIA. In August 1851 the governor informed Earl Grey that a large deposit of gold had been found in the colony at Clune's diggings, about 40 miles from Melbourne, in quartz gravel, and at Ballarat on the river Leigh, 75 miles from Melbourne, in fragments of slate rock. The most productive locality was Ballarat. The total production of Victoria for 1876 was about 1,000,000 ounces, of which 400,000 ounces were from alluvial, and 600,000 ounces from quartz mining. This yield was 100,000 ounces less than that of the previous year. The growth of the colony as a mining country will be inferred from the statement that at the beginning of 1876 there were 1,101 auriferous quartz reefs actually worked upon, and 3,208 more were proved to be auriferous. About 42,000 persons were employed in mining, of whom 11,000 were Chinese. The largest amount raised in one year was 2,985,991 ounces in 1856. In 1879 the production of gold from alluvial mining was 293,310 ounces, and from quartz mining 465,637 ounces.

TASMANIA.—The discoveries extended southwards to Tasmania or Van Diemen's Land, and this island contributed its share of the gold production of 1875 : of 850 ounces from alluvial, and 3,800 ounces from quartz mining, making a total of 4,650 ounces.

QUEENSLAND.—If to the foregoing amounts we add 50,000 ounces from Queensland, we have a total of 1,272,760 ounces of gold as about the present annual production of the Australian continent and Tasmania. The proportion, taking the whole area from alluvial and lode mining being about equal.

The sources of this gold are to be found in the range of mountains that, at some distance from the east coast, extends from Cape York peninsula on the north, southward through North Australia, Queensland, and Victoria, and which, ramifying westward in the latter colony, reappear to the south in Tasmania. For gold, the first-named colony does not now require notice.

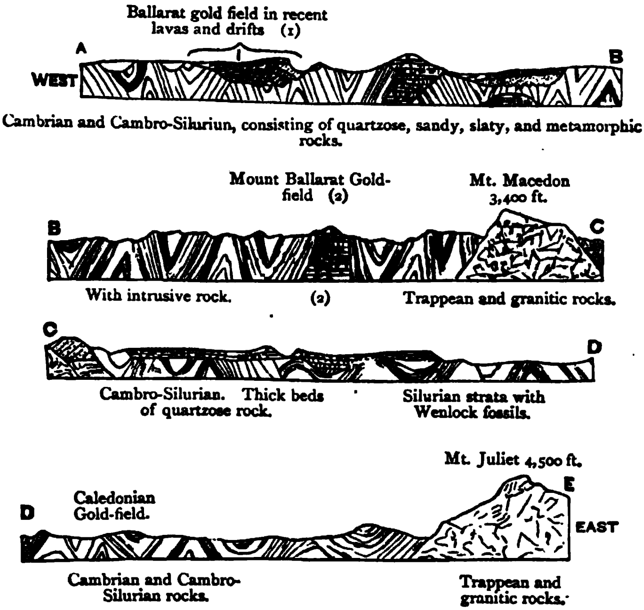


FIG. 23.—SECTION OF STRATA THROUGH THE GOLD DISTRICTS OF VICTORIA.

The general structure of these mountains, throughout their entire length, is shown on the section fig. 23, which is adapted from the Government survey of that country.

It will be seen that the geological structure of the country in the age of the gold-bearing rocks is the same as those of the countries we have already noticed. There are the usual fundamental granitic and gneissic rocks, on which rest Cambrian and

Silurian rocks in all their varieties, and from which fossils, characteristic of the different groups of strata, have been found.

These older rocks are traversed by quartz beds and veins, locally known as reefs, that coincide for the most part with the strike of the beds. Fig. 24 represents an auriferous quartz reef, and the methods by which it is approached and mined.

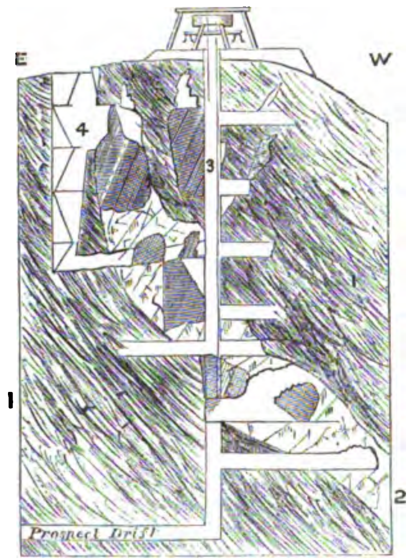


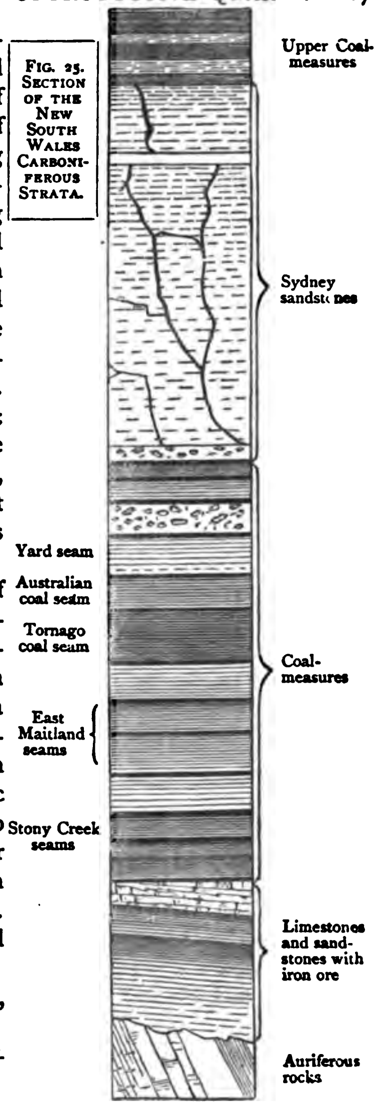
FIG. 24.—AURIFEROUS GOLD REEF, NEAR BALLARAT, WITH METHOD OF WORKING.

1, Granitic rock. 2, Quartz reef. 3, Shaft. 4, Shallow workings with ladders.

The whole of the quartz veins and beds are not auriferous, for there are long stretches of barren reefs alongside those that are productive. In the latter the gold is usually associated with iron pyrites and titaniferous iron—the source of the emery that accompanies the gold in the alluvial deposits. The productiveness of the quartz or otherwise appears to depend chiefly upon the age of the quartz, and, as in Brazil, on the

presence also of iron pyrites. There is a good deal of quartz in Australia of younger age than that of the gold-bearing reefs lying near the base of the Coal-measures. The following vertical section, fig. 25, will show the relative position of the two quartz rocks, and it will be useful when we come to consider the copper deposits of the country. Mr. Keene[1] observes: 'There is a quartz at the base of the Coal-measures, in many cases of great purity, in which gold has been sought for in vain.'

FIG. 25. SECTION OF THE NEW SOUTH WALES CARBONIFEROUS STRATA.



The productiveness of the quartz reefs seems further to depend upon the nature of the strata with which they are associated. As a rule, the quartz reefs are auriferous as they pass through hornblendic or porphyritic rocks, and cease to be so when they enter schists, or the metal does not then occur in paying quantities. Diorite is also associated with the best paying lodes.

Mr. Wilkinson, F.G.S.,

[1] *Quarterly Journal Geological Society*, vol. xxi. 139.

Government Geological Surveyor of New South Wales, has recently suggested an instance in which, as he thinks, a gold deposit has been derived from the conglomerates of the Coal-measures, pointing to the inference that those conglomerates are themselves auriferous.[1] Fig. 26 is a reproduction of his own illustration as far as it concerns this idea, but an examination of it must, I think, show Mr. Wilkinson's inference to be erroneous. A geologist will see that the Coal-measures once extended right over the Cambro-Silurian rocks, D, so that the correct inference is that the gold deposit, E, must have been derived from the abrasion of those rocks, and formed *prior* to the deposition of the overlying Coal-measures. It has become exposed by the subsequent denudation of the

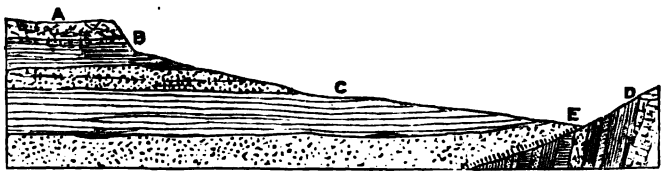


FIG. 26.—ILLUSTRATION OF GOLD DRIFT AT THE BASE OF THE COAL-MEASURES, NEW SOUTH WALES.

A, Gardner's Hill. Basalt, soft. B, Thin layer of tertiary pliocene drift. C, Coal-measures. D, Silurian sandstones, with shales and quartz reefs. E, Place of gold workings.

Coal-measures at the spot. I am the more careful to point out this mistake, as I deem it, because I am sure that it is from similar errors, where a newer formation rests unconformably upon one much older, that statements concerning the deposits of gold *in situ* in the Upper Secondary rocks have been made concerning California. If, however, Mr. Wilkinson only intends to show an auriferous drift of Carboniferous age, no objection can be offered to the endeavour.

The intimate structure of one of the smaller quartz veins containing gold is shown in figs. 27 and 28, which I have adapted

[1] *Annual Report of the Department of Mines, New South Wales,* for the year 1876, p. 166.

from an illustration by Mr. Richard Daintree, F.G.S.[1] The gold is represented by the dark lines in the centre; the quartz on

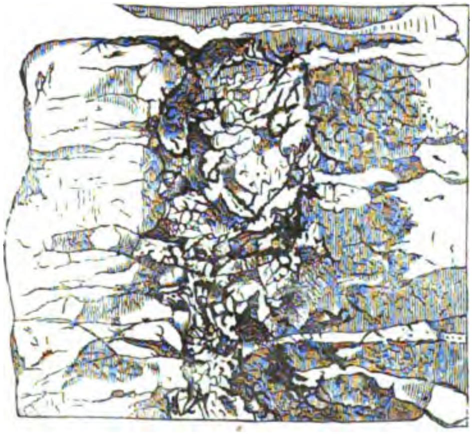


FIG. 27.—SHOWING THE INTIMATE STRUCTURE OF A GOLD QUARTZ REEF IN NEW SOUTH WALES.

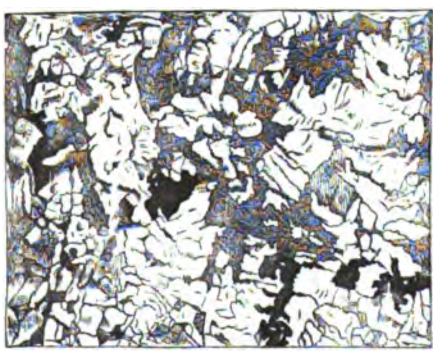


FIG. 28.—SHOWING THE INTIMATE STRUCTURE OF A GOLD QUARTZ REEF IN NEW SOUTH WALES.

either side is barren of gold, which seems to have been among the last substances deposited in the crack, or the gold may have

[1] 'On Certain Modes of Occurrence of Gold in Australia,' R. Daintree, F.G.S., *Quarterly Journal of the Geological Society*, August 1878, p. 438.

been deposited afterwards in a subsequent reopening of the crack. Besides occurring associated with pyrites in granite rocks, gold also occurs disseminated in pyritous diorites, in pyritous felsites, and also in pyritous quartz and calcspar veins, usually well defined, wide, and persistent, by which these rocks are traversed, and into which the disseminated mineral has been mechanically and chemically gathered.

The 'reefs' are productive to a great depth. In Victoria about thirty mines have reached a depth ranging from 1,000 feet to 1,800 feet. The Newington Mine is 1,940 feet deep. Sixty-five tons of quartz, mined from a depth of 1,060 feet, gave 8 ounces of gold to the ton; but this must have been selected quartz. The impression has prevailed lately that quartz does not, as a rule, pay for mining at a greater depth than 1,000 feet. Possibly this idea, like many before it, may vanish before increasing skill. The proportion of gold to the ton of quartz crushed varies considerably, as the following particulars, relating to 1876, will show: 11,500 tons from Stawel, Victoria, obtained at depths varying from 430 feet to 1,060 feet, gave from 1 oz. 3 dwts. to 5 ozs. 14 dwts. to the ton; 5,890 tons from Sandhurst, from depths of 500 feet to 1,000 feet, gave from 1 oz. 14 dwts. to nearly 2 ozs. per ton; South Clunes Mines gave from 2,171 tons, 8 dwts. 9½ grs. per ton; and Port Phillip Colonial Gold Mine worked 4 dwts. 8 grs. per ton at a profit. In the third quarter of 1875, 259,997½ tons of quartz crushed in Victoria, gave an average of 12 dwts. 13½ grs.; in the first quarter of 1877, the average yield was 10 dwts. 17 grs. The average yield may therefore be taken at 11 dwts., an average that seems to be pretty constant, for the proportion per ton from 5,811,669 tons 9 cwts. of quartz, crushed during the ten years ending 1868, was 11 dwts. 12·37 grs.

As elsewhere, the earliest discoveries and works were made in the drifts that fill up the valleys and cover the plains that are spread out at the feet of the mountains, and still, as we have seen, a large proportion of gold is derived from this source. We shall gain an idea of the structure and composition of these drifts by a perusal of the following detailed sections:

SECTIONS OF DRIFTS IN AUSTRALIA.

Golden Rivers.	*Steiglitz.*
1. Uppermost drift, filling up hollows and erosions in the drifts below, and gold bearing.	1. Uppermost drift, filling up hollows in the drift below, gold bearing.
2. Upper Basalt rock, 25 feet to 30 feet.	2. Upper Basalt rock, 49 feet.
3. Pliocene gravel, gold bearing, 50 feet to 60 feet.	3. Sandy grits (Pliocene), gold bearing, 10 feet to 15 feet.
4. Absent.	4. Upper Coralline Limestone, 13 feet.
5. Absent.	5. Older Basalt, with limestones and fossils. } 30 feet.
6. Absent.	6. Sandy Limestone, with fossils. } 30 feet.
7. Miocene gravel, not productive, the false bottom of miners, 40 feet.	7. Rounded quartz pebbles and hard silicious conglomerate rock, with gravels and boulders, 90 feet.
8. Thin bed of drift-clay, with gold.	. Layer of clayey drift, with gold.
Cambrian strata.	Cambrian strata.

One or more members of the series, as shown in the complete Steiglitz section, is frequently absent, as shown in the diagram sections, figs. 29, 30, and 31, which are adapted from Mr. R. Brough Smyth's complete and valuable work.

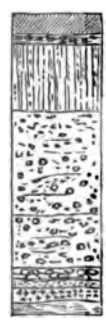


FIG. 29.—SECTION AT DARLOTS.

When the recent drifts that lie on the surface are worked for gold, the operation is called surface or shallow mining; but the operations by which the deeper and older auriferous drifts are reached, are known as deep sinking. This lowest auriferous drift lies immediately upon the eroded surfaces of the usually upturned edges of the Cambrian strata. They fill hollows and old river courses along the surface of these beds, which are often followed for miles. These long troughs and river-courses are

called 'leads,' and fig. 32 will give an idea of their position as

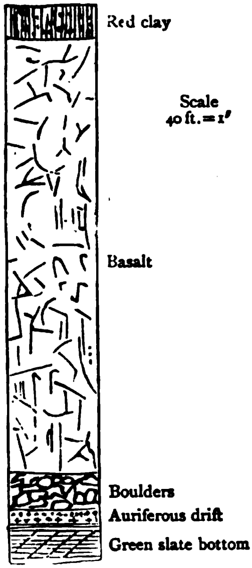


FIG. 30.—SECTION AT LUCKY WOMANS.

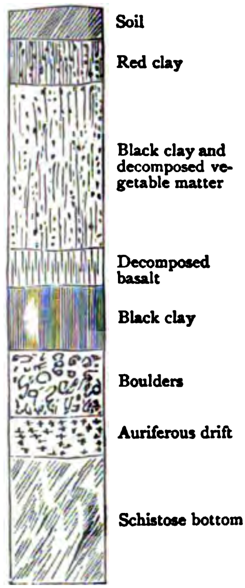


FIG. 31.—SECTION AT LINTONS.

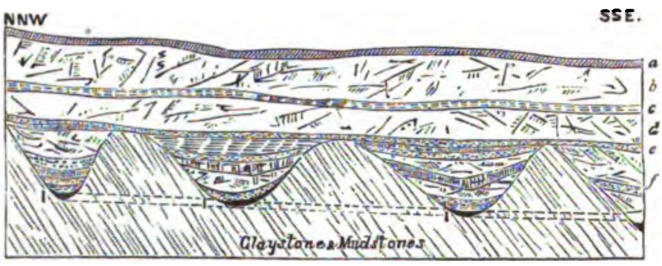


FIG. 32.—SECTION OF THE OLDER DRIFTAL GOLD DEPOSITS NEAR BALLARAT.
Scale: Hor. 1" = 10 chains; Vert. 1" = 320 feet.
a, Drift. *b*, Basalt. *c*, Black and red clays. *d*, Basalt. *e*, Light coloured clays. *f*, Basalt. 1 1 1, Auriferous drift.

they occur in the neighbourhood of Ballarat, as well as of the

way in which they are often approached by adit levels, and connected by levels driven through the intervening strata.

Fig. 33 represents a similar deposit on the Macquarie River, New South Wales. It is interesting by way of comparison with the sections from Ballarat, as showing the newer auriferous drift approached by a shaft, and also the contrast between the present river valley of the Macquarie and the ancient watercourse.

A neighbouring section shows the basalt, which, as in Victoria, spreads over the older drifts, and has helped to preserve them from denudation. The shaft passes through

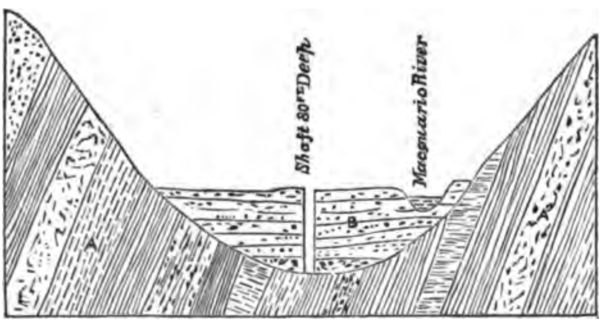


FIG. 33.—SECTION OF NEWER GOLD DRIFT ON MACQUARIE RIVER.
A, Silurian strata. B, Drift-sand and gravel.

Loam sand and clay	40 feet.
Vesicular basalt	130 feet.
Light pebble drift and gold wash, cemented in places with oxide of iron and iron pyrites, containing fragments of wood and coaly shale. The drift yields 5 dwts. to the load . .	5 feet.

The gold is found in these drifts in grains and nuggets, one of the latter reaching 600 ounces. In 1876, 574,1·64 tons 2 cwts. of drift washed in Victoria, gave an average of 22·67 grains per ton. 35,938 tons of cement or drift caked together were crushed, and gave an average of 4 dwts. 13¼ grs. per ton.

In New South Wales the average yield of gold per ton of drift for 1875 was 5 dwts. 9·58 grs., but it is explained that this high average came from 58,081 tons of selected wash dirt. The average from 172,630 tons of drift in 1876 was 1 dwt. 23·14 grs.

CHAPTER X.

GOLD—continued.

New Zealand—History—Gold *in situ*—Gold in Drifts—Africa—Gold Fields of Leydenberg—India—Philippine Islands—Aruba Island—Concluding Remarks.

NEW ZEALAND.—Returning eastward a little way we find a similar range of mountains to those of Australia running N. and S. down the two islands of New Zealand. The section, fig. 34, adapted from one of Dr. Hector's,[1] the Government

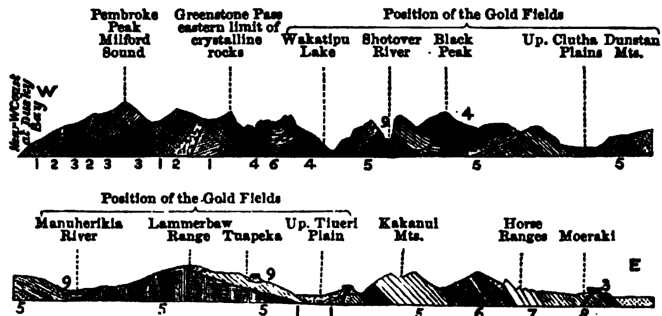


FIG. 34.—SECTION ACROSS THE PROVINCE OF OTAGO.

1, Gneissic granite. 2, Dykes of diorite, &c. 3, Granitoid, porphyritic, and syenitic rocks. 4, Quartzites, slates, felstones, serpentine, and marble. 5, Grey, blue, and contorted foliaceous schists. } Gold-bearing strata. 6, Sandstone and porphyritic rocks. 7, Carbonaceous sandstones, with brown coal. 8, White crag, with fossils and tufaceous rocks and basalt. 9, Ancient lake deposits, with brown coal. The great gold drift.

geologist for that colony, gives a detailed description of the gold-bearing rocks, with their associated strata, together with the gold-bearing drifts.

[1] Dr. Hector, *Quarterly Journal Geological Society*, vol. xxi. 124.

Up to the year 1857 there was no gold mine in New Zealand, but in the twenty years ending last year, no less than 8,038,571 ounces of gold had been obtained. The yield for 1874 was 14,306 ozs. 17 dwts.

The quartz occurs both as filling up fissures and as irregularly stratified beds. Both the lodes and beds are contained in a series of strata (4 and 5 of section), which are divisible into three parts: first, the upper grey arenaceous slaty rock, which does not contain much quartz, either in veins or beds; second, the middle part, about 200 feet thick, which is made up of soft blue micaceous slates, traversed by small quartz veins of a decomposed nature, especially near the surface. This is supposed to be the source whence the detrital gold of the Western, or Lake Gold Fields, has been derived. Thirdly, the lower part, made up of clay slates, often chloritic and contorted and foliated with quartz, especially in its lower portion.

The quartz laminæ are concretionary in their structure, of a bluish colour, and horny in appearance. Besides the gold found in the quartz lodes and beds, the metal occurs segregated in the interstices of the contorted schists, but it is not worked *in situ.*

One of the richest gold-bearing districts is that of Coromandel, in the northern island, near Auckland, and among the mines may be mentioned that of Kapanga, where good gold is found in a quartz vein, four feet wide, at a depth of 300 feet from the surface. The yield of gold from some of the auriferous reefs is as much as 1 ounce to the ton, but the average is considerably less. The drifts, like those of Australia, are both recent gravel sands and ancient driftal deposits. The latter are in places like old lake deposits, in which gold is associated with brown coal. They follow the range of the mountains from north to south.

Retracing our steps to the Old World, I will briefly notice the recently discovered gold deposits of South Africa.[1] A range of mountains extends at some distance inland along the eastern

[1] See Dunn, *Quarterly Journal Geological Society*, vol. xxxiii. p. 879.

coast of Africa, from the Red Sea to the Cape of Good Hope. NE. in their ramifications through Arabia they form the depositories of the gold of Midian, to which Captain Burton has just directed attention. It is probable that ultimately gold, both *in situ* and in driftal deposits, will be found all along the course of this range; but at present the gold fields are confined to the portion that lies between the Zambesi on the north, and Cape Colony on the south, in the north part of the Transvaal, the chief mining operations being grouped around Leydenberg, lat. 23° 40′ S., and long. 31° E.

Fig. 35 will afford an idea of the geological structure of the district, which is of the usual kind, underlying granites, gneiss,

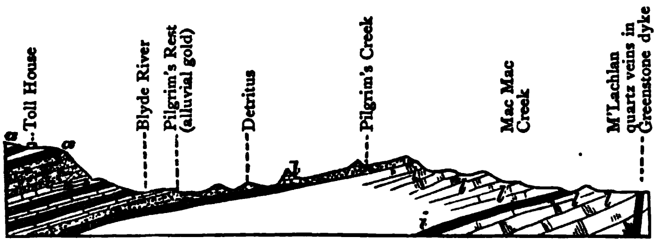


FIG. 35.—SECTION THROUGH THE LEYDENBERG GOLDFIELD, SOUTH AFRICA. Horizontal scale 1″=4 miles; Vertical 1″=4,000 feet.

a, Quartz rock. *f*, Fissile sandstones. *g*, Soft pink sandstones. *h i*, Pink, blue, grey, and brown sandstones, much jointed. *k*, Cherty limestone. *ll*, Limestones. ||||||, Greenstone.

and greenstones, succeeded by laminated mudstones, white and red quartz, bedded rocks, calcareous strata, with thin layers of quartzite between the bedding and quartz breccia, like quartz rock shattered, and the cracks filled with newer quartz.

In 1864 Dr. Mann found gold in a high granitic tableland, forming the watershed of the rivers Lipalule and Limpopo, in which there were numerous traces of ancient mining. Mr. Bains also found some considerable clusters of reefs near the Zambesi. Quartz reefs were also found 200 miles NW. of Leydenberg, some of which were worked by Englishmen. The ancient mines seem to have been worked on the reefs as open quarries. There were recently eleven mines at work in the

quartz rocks, and a description of one of these will illustrate the general character of the rest. The Erstellung Mine is situated near Marabastadt, in lat. 24° 5′ S., and long. 29° 55′ E. The strata are composed of chloritic and steatitic schists, which dip at an angle of about 80° N. These schists rest on gneiss, and are overlaid by the gold-bearing rocks of Leydenberg. The principal reef worked, the Natalia, is about three feet wide, and follows the bedding. The gold is sprinkled throughout the quartz, and it is also accumulated in the cavities. The yield of the reef is stated at 1 ounce of gold per ton of quartz. The reef is accompanied along its course by dykes, probably beds, of diabase, and it is crossed by dykes of dolerite.

At Leydenberg the gold occurs both in flat beds of quartz, and also in strings or veins interbedded with and intersecting the limestones l l of the section.

The principal locality where driftal gold is found in South Africa is at Pilgrim's Rest Creek, which is thirty miles due west of Leydenberg. The creek is about three miles long, and flows west into the river Blyde. The drift in the creek is from five to twelve feet deep. At the top it consists of fine alluvium; this is succeeded downwards by clay, in which are imbedded pebbles and fragments of the adjoining rocks. Below this, and resting upon the solid rock, is the bed of auriferous drift, about one foot thick. The gold is found in grains and nuggets, the whole of which are rounded and coated with oxide of iron. The quality of the gold is valued at from 3*l.* 10*s.* to 4*l.* per ounce. Diggings are also worked at Mac Mac Creek, where the drift is made up of slaty sandstones and calcareous fragments. There is an absence of the great boulders that rest in the auriferous drift of Pilgrim's Rest. The gold is scarcely equal to that of the latter place, and it occurs in finer grains. The yield of gold from South Africa is estimated at the value of 60,000*l.*, but it is believed that the total amount reaches nearly double that sum.

OTHER COUNTRIES.—Gold is found under similar conditions in other countries. The Shah of PERSIA is said to have remitted half the taxes of the subjects of the province of Zingan in

that empire where gold has recently been found. In North Western India detrital gold is found in the sands of River Ramyunga, which has its source in the Himalayas; also in the gravel of the Alukunda and the Pindur, out of which gold was formerly washed by the natives. It has also been observed in quartz veins in granite at Kurmaon and Gurwahr. In CHINA it is worked and is almost exclusively in the hands of the mandarins, to whom the miners are obliged to sell gold at 42*s.* for every 100*s.* of its value. From the difference of 58*s.* the mandarins pay a tax of 10*s.* to the Government, and pocket the difference.

The PHILIPPINE ISLANDS contain gold which has not as yet been much worked by European enterprise.

ARUBA ISLAND, one of the Leeward Islands of the Caribbean Sea, has both auriferous quartz reefs and drifted deposits. In 1875, 889 tons of ore were shipped from this island, which gave 13 dwts. of gold, valued at 2*l.* 12*s.* per ton. Recently the metal has also been found in New Guinea.

Concluding Remarks.—From the foregoing descriptions it will be seen that gold occurs in rocks of the same age and under similar conditions all the world over. That for the most part gold-bearing rocks lie below the Carboniferous group. That the general horizon of the most productive rocks lies at what in North Wales is the junction of the Lower with the Upper Cambrian, the horizon of the Lingula flags and the beds below. That schists or slates of a steatitic, talcose, and chloritic nature, with granitic and greenstone rocks of the same age, are the best depositories of gold. That it is finely and sparsely disseminated throughout the whole of the above rocks, but segregated in quartz beds and veins. That in quartz it is most abundant where iron pyrites, titaniferous iron, and other ores of iron prevail. That the idea of twenty years ago, that gold was thrown up to the surface of rocks and died out in depth, is not correct, as, indeed, it might have been expected it was, since, theoretically, no present surface of rock was the original surface. Practically, and as a matter of fact, gold is now profitably worked to a depth of 1,000 feet and more. That the continuation of gold in paying quantities downwards,

depends more upon the nature of the rock traversed by quartz lodes than upon the depth itself. Finally, that it is probable that in Africa, India, Persia, and everywhere where the great mountain ranges composed of the rocks described come to the surface, gold *in situ* will be found abundantly, as explorers pay the same attention to them that they have done in California and Australia. All along these mountain ranges detrital deposits containing gold may also be found. There is, therefore, no ground for the fear sometimes expressed that the world's gold supply will fail, especially if some simple invention be conceived by which the sea-sand of the shores of auriferous countries, like the black sands of the Californian and Oregon coast, shall be made to yield readily and cheaply their contained particles of gold.

CHAPTER XI.

SILVER.

General Characteristics—Its Ores—Silver in Russia, Austria, Bohemia, and Saxony—Description of the Mines of the Erzgebirge—Hanover and Brunswick—Nassau—France, Spain, Norway, and Great Britain.

NEXT to gold, silver is the most useful and precious of the metals. Its hardness is described as 2·5, and its gravity as 10·3 to 10·5. In hardness it is therefore the same as gold. It is less malleable than gold, the thinnest leaves into which it can be beaten being the 160,000th part of an inch thick. In colour and streak it is silver white and shining, but is sometimes tarnished yellow, red, brown, and black.

Silver occurs in nature in a native form, in which it is usually alloyed with some other metal: sometimes containing as much as 10 per cent. of copper and 16 per cent. of bismuth. It also occurs, and more abundantly, in a mineralised form, as ore, in which it is associated with arsenic, bromine, iodine, selenium, and sulphur, and also in combination with various acids. The following are the principal of these combinations:

ORES OF SILVER.

SILVER GLANCE.—Sulphide of silver, composed of 87·04 parts of silver and 12·96 parts of sulphur. This ore has a metallic lustre, is of a dark grey colour, and has a shining streak. It is the common and most valuable ore of silver. The rarer varieties of this ore, in which the silver and the sulphur are mixed with other minerals, are:

1. *Brittle Silver Ore.*—Composition: Silver 68·5, sulphur 16·4, antimony 14·7, and copper 0·6.

2. *Antimonial Silver.*—Silver 77·0, antimony 23·0.

3. *Polybasite.*—Similar to brittle silver ore, but containing arsenic and copper.

4. *Miargyrite.*—Silver 36·5, with antimony and sulphur in larger proportions than British silver.

Ruby Silver.

5. *Dark Red Silver Ore.*—Silver 59·0, with antimony and sulphur, coloured to black with a red streak.

6. *Light Red Silver Ore.*—Silver 65·4, with arsenic and sulphur. Colour cochineal red.

7. *Euchairite.*—Films of silver and copper, containing selenium.

8. *Telluric Silver* (Hessite).—Silver 62·8, and tellurium 37·2, said to be found only in Siberia. Contains sometimes a considerable proportion of gold.

9. *Xanthocone.*—Silver 66·2, with sulphur and arsenic.

CHLORIDE OF SILVER, or HORN SILVER.—Composed of 75 parts of silver and 25 parts of chlorine, but usually contains a small quantity of the peroxide of iron. It is grey in colour, and of a horny or waxy appearance. In a flame it emits acrid fumes. It is the common ore of the Mexican and South American mines.

Its varieties are:

1. *Bromic Silver.*—Containing an admixture of bromine.

2. *Iodic Silver.*—Containing an admixture of iodine.

3. *Embolite.*—Composed of silver 67, bromine 20, and chlorine 13.

In describing the quality of silver, it is said when perfectly pure to be silver of twelve pennyweights. If it contains one twelfth part of alloy with other metals it is silver of eleven pennyweights, and so on downwards in the scale of quality.

Following the plan adopted in the description of the localities and modes of occurrence of gold, I will begin again in the East, and will notice the chief mining localities westward.

RUSSIA.—On the east of Lake Baikal, in the southern part of Central Siberia, are the mines of Nirchchinsk, which are worked in a crystalline limestone for a lead ore that is largely

charged with silver. Westward along the same latitude are the Kolivan mines of the Altai mountains, where silver ores are obtained from Cambro-Silurian schists, interstratified and intersected with porphyritic rocks. The silver ores are here associated with those of copper, gold, and lead. The production of the whole empire may be estimated at 60,000 lbs. troy.

AUSTRIA has long been a great silver-producing country. It will be convenient to describe first the mines of Hungary, and secondly those of Bohemia.

Hungary.—The mining region of Hungary is usually divided into four districts : 1, Upper Hungary, around Schmöllnitz ; 2, Lower Hungary, near Schemnitz, Kremnitz, and Neusohl ; 3, Nagbanya, on the western limits of Transylvania, and 4, the Banat, around Oravicsa and Szaska. The mines of Lower Hungary and the Banat are best known. The lodes of Schemnitz and the neighbourhood traverse a boss of greenstone porphyry, in which they are productive, but cease to be so when they enter the trachyte that overlies and surrounds it. They run from east to west. They are nearly parallel to each other, from about 1,000 to 2,000 feet apart. There are seven principal lodes in one group, the chief one of which—the Spitalberg—extends a known distance of three miles, and is from ten to twelve feet wide. Silver prevails at the western end of this lode, galena at the eastern end. At the Windschact a depth of 330 yards was attained on this lode, where bunches of silver ore were found scattered throughout the gangue, which was largely composed of felspar.

Another lode, the Biebergang, was worked to a depth of about 1,300 feet, and for a length of three miles. It yielded an immense amount of silver, but in this and in the other lodes beyond this depth the silver gave place to galena, which was less and less argentiferous.

The mining district of the Banat,[1] to which a reference has been made already, forms an irregular oval area, whose longest axis is north and south. It has a base of granitic and gneissic

[1] See also *Mining Journal*, 1877, p. 795, *et seq.*

rocks, as seen in fig. 17, and in fig. 36, on which rest felspathic and porphyritic rocks. Sometimes limestones rest in the troughs between the north and south ridges, and frequently these ridges are thrown up in the midst of altered cretaceous limestones, which abut against them. Most of the mineral deposits belong to the group of contact deposits, and are usually richest in mineral near the surface. The minerals found are very various—gold, silver, copper, lead, zinc, and iron. Most of the minerals seem to have been deposited as

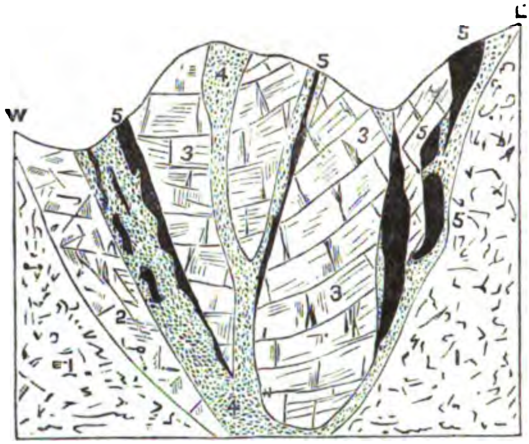


FIG. 36.—CROSS SECTION AT SIMON JUDAS MINE, BANAT.
1, Syenitic Rocks. 2, Gneissic rock. 3, Limestone. 4, Vein. 5, Mineral Deposits.

sulphides, which character they retain in depth; but near the surface, through contact with the atmosphere, they have become oxidised. As a rule, the deposits become poorer for minerals, both as to quantity and quality, southwards.

Silver is found, in a group of mines near Dognacska, associated with lead and copper. At the Barbara Mine the ore is dressed into three qualities: (1) Oxidised lead ores, containing 20 per cent. of lead and 10 ounces of silver to the ton; (2) galena, with 34 per cent. of lead and 16 ounces of silver to the ton; (3) cupreous pyrites, containing 1 per cent. of copper

and 18 ounces of silver. These mines are worked in deposits that lie between a dyke of syenite and overlying limestone; the ore is usually found on the upper side of the deposits, under the hanging wall of the limestone. At the old mine of Simon Judas, fig. 36, the ore was an argentiferous copper. The ores were copper glance and copper pyrites, which, in the upper part of the mine, contained 30 per cent. of metallic copper and 18 ounces of silver to the ton of ore, but the ores became so poor in depth as not to be worth following downwards. At another mine, the Jupiter, the gold associated with mundic contained 15 per cent. of silver.

BOHEMIA AND SAXONY.—Crossing now to the north-west of Austria, we reach the range of the Erzgebirge, or Silver Mountains, that divide Saxony from Bohemia.[1]

This is the classic ground of German metalliferous mining. Here it was that Werner taught, and here he started that controversy between Aqueous and Plutonic forces, and the part each has played in the history of the earth, which even now, after the lapse of a century, disturbs and divides geologists. Here, too, as the result of careful plodding work, the Germans have attained the van of scientific mining.

About the year 1170, a Bohemian labourer travelling near Freiberg, then covered with a vast forest, sat down to rest himself on a stone by the wayside. He saw a stone lying at his feet, like others he had before seen in the Hartz. He carried a part of it with him on his way, and as soon as he could he had it tested. It proved to be galena, rich in silver. He returned with some comrades, and searched for the lode from which he supposed the stone had been derived, and was successful. Some years afterwards, the Duke of Brunswick having offered an outrage to the wife of an officer of the mines in the Hartz, the miners revolted, deserted the mines, and following as a leader one of the discoverers of the Freiberg lode, established themselves in a village near it, which they

[1] Daubisson, *Des Mines de Freiberg*; Weissenbach, *Gangverhältnisse aus dem sächsischen Erzgebirge*; *ibid.*, *Ueber Gangformation*; Percy, *Metallurgy of Lead.*

called Christiansdorf, which afterwards came to be called Freiberg. The mines grew in number and in production, enriching the miners, and also the royal owners of the soil. The town became prosperous and rich. It, with the whole district, suffered in the different wars, especially during the Thirty Years' War; but it again prospered, and became famous for the school of mines, of which Werner was a distinguished professor. Even now, although some of the mines are exhausted and others are worked at great depths, it is the chief mining centre of Europe.

The greater proportion of silver produced by Saxony and Bohemia is obtained from the Erzgebirge. Fig. 37 shows the general structure of this range of mountains. The central boss or ridge of these mountains is composed of granite, 1, which in its upper portion passes on both sides into gneiss 2 2. The gneiss

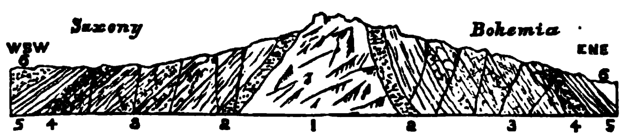


FIG. 37.—DIAGRAM SECTION ACROSS THE ERZGEBIRGE.

is succeeded by a series of micaceous slaty rocks, 3 3, which in their turn are covered by a succession of clay slates, 4 4. Then come the Carboniferous rocks, 5 5, and the Permian, 6 6. The succession of the strata is the same on both sides of the range, but the Bohemian side is the steepest.

Between the beds of gneiss there are beds of quartz, together with bedded and irregular porphyritic rocks. The micaceous and clay-slate beds also, as in this country, contain many beds of porphyry, trap, and limestone, together with beds impregnated with iron pyrites. The granite is composed of fine grains of felspar, quartz, and mica, the latter giving to it a somewhat leafy texture. It is also traversed by thin basaltic dykes and quartz veins, and, as may be supposed, it forms the highest peaks of the range. The gneiss is formed of white felspar, quartz, and mica, running in sinuous layers. Besides

these, its regular constituents, it contains in places schorl, tourmaline, and earthy and steatitic substances—the latter probably decomposed felspar. The gneiss varies in hardness; where the quartz prevails it is as hard as granite, while towards the surface and near the veins it is tender, and offers but slight resistance to the miner. It is regularly stratified, and the dip of the beds varies considerably. Close to Freiberg it is nearly horizontal; to the north its ridges are parallel to the mountain range; to the south the dip inclines south-west. Interstratified with the gneiss and slates, which I have already described, there are, as I have said, beds of compact felspar, hornblende, calcareous matter, and layers of pyrites.

The strata described are traversed on the Saxon side of the range, and within no great distance of Freiberg, by about nine hundred lodes, which are classified into four groups, each group having more or less affinity with the rest.

The First Group, sometimes called the Precious Quartz Group, consists of quartz veins. It comprises about 150 lodes, which range from six inches to one foot in width, and which have a direction NNE. by SSE., with a dip or inclination of 70 to 80 degrees to the west. The quartz is often intermixed with fragments of the adjoining rock, and is sprinkled with pyrites. It contains druses and cavities, in which, and in nests irregularly distributed throughout the lodes, lie the metalliferous minerals. The silver ores contained are silver glance, polybasite, miargyrite, stephanite, and pyragyrite, together with arsenical pyrites and antimonial silver ores. These lodes are well developed near Braunsdorf, where they are richest in a dark carbonaceous slaty rock, and become poor as they pass into the micaceous.

The Second Group consists of brown spar veins, and is also known as the Precious Lead Group. It numbers about 340 lodes, which, besides containing quartz, are charged with diallogite and the spathic carbonates, chiefly brown spar. The metallic ores are galena, rich in silver and blende, with iron pyrites. These minerals are often beautifully arranged in layers. In the cavities are also silver ores and lumps of native silver,

one of which has reached one hundredweight. These lodes have a north and south direction, and dip to the west.

The Third Group is composed of lodes, whose matrixes are the oxides and carbonates of iron mixed with fluorspar and sulphate of baryta. This is also known as the Barytic Lead Group. It numbers about 130 lodes, which are occasionally of great size, and present some fine examples of the banded structure of veins. Lodes of this group traverse the higher Carboniferous and Permian groups of strata, and they are strongest and contain most silver ores north of Freiberg.

The Fourth Group prevails east of Freiberg, and consists of veins from two to three inches wide, of which there are about three hundred. The gangues are carbonate of lime, sulphate of baryta, and fluorspar. The metalliferous ores comprise galena, blende, copper and iron pyrites, mispickel, and the usual silver ores. The galena contains 10 to 60 ounces of silver. It is also known as the Pyritic Lead Group. These lodes become, as at the Jungehohebirke and Morgenstern mines, cupriferous when quartz prevails as a matrix, and then the metalliferous ores are the red and black oxides, and the blue and green carbonates of copper with copper pyrites, vitreous copper with silver and purple copper ore. These copper ores contain about 10 ounces of silver to the ton, and a slight proportion of gold. The average proportion of silver in the galena of this region is 49 ounces. In ordinary vein stuffs 16 ounces to 30 ounces to the ton of ore is the varying proportion.

On a more limited scale this description of the Freiberg district will apply to the Bohemian side of the range. The average depth to which the lodes have been worked is 1,500 feet, and at this depth they are persistently rich in ore.

Observations made during a great number of years seem to point that the productiveness of lodes depends among other things on the power of the enclosing strata to conduct heat and electricity, and hence upon their composition and density, so that certain rocks are called 'carriers'—the moderately dense slates and gnessic rocks possessing these qualities.

The Rothschönberg tunnel just completed is nearly twelve miles long, and will drain these mines to a depth of 1,700 feet.

The annual yield of silver from the Bohemian side of the range may be estimated at 30,000 marks. The total production of Austria is about 110,000 marks. The annual production of Saxony from the Erzgebirge is about 60,000 lbs., which has been the average for a great number of years.

HANOVER AND BRUNSWICK.—Another great centre of German mining industry is the Hartz range of mountains, the strata and lodes of which will be more fully described when we come to speak of lead. It is only necessary to observe further now that the lead ores of this region are among the richest in Europe for silver. The annual production of the district may be estimated at about 30,000 lbs.

NASSAU.[1]—Passing down the centre of Europe, we cross the highly-mineralised little duchy of Nassau, whose production of silver is equal in value to 30,000*l.* A good proportion of this is obtained from lead ores, which contain from ·003 to ·006 per cent. of silver. In some instances the silver reaches 1 per cent. of the ore. Clean ores, free from impurities, are found in the breccia of lodes. Silver ores proper also occur in quartz lodes near Holzappel; and spots, plates, and dendritic incrustations of silver occur in lodes filled with quartz; and brown ironstone and covering lead ores near Oberlahnstein.

FRANCE.[2]—Passing from Germany to France, nearly all the lead-producing mines give silver, and special mention may be made of the following principal mining centres where silver is produced: 1. The département d'Isère, des Hautes-Alpes; 2. département du Puy-de-Dôme, in Central France; and 3. département des Basses-Alpes, du Var, and des Alpes-Maritimes. The total amount of silver produced in France amounts to about 50,000 kilogrammes.

In the department of Isère, south-east of France, silver was first found in 1767, by a goatherd who was looking for his kid,

[1] Odernheimer, *Das Berg- und Hüttenwesen im Herzogthum Nassau.*

[2] Cailloux, *Mines Métalliques de la France*; Henwood, *Metalliferous Deposits.*

in Chalanches d'Allemont, a spur of the great Alpine chain. The axis or foundation of this part of the Alps is a coarse granite, that changes occasionally into gneiss, both granite and gneiss changing occasionally into fine-grained crystalline masses. They are overlaid by hornblende slates, into which the gneiss graduates. The general direction of the beds is north and south. Traversing these rocks are eight principal lodes, which run at varying distances from each other east and west. They have a dip of 50 to 70 degrees, chiefly to the north, but varying along their course. These lodes range in size from 6 inches to 2 feet 6 inches wide. They are filled up largely with the materials of the rocks they traverse, but they also contain calcareous spar, felspar, quartz, and hornblende, with smaller proportions of asbestos, chlorite, epidote, mica, and talc. Silver is found in these lodes in a variety of forms—native, mixed with antimony, with antimony and sulphur, and with sulphur and salt. The ores are most plentiful in a matrix of earthy brown iron ore, and also where the lodes are charged with calcareous spar, chlorite, and asbestos. Other metallic minerals are associated with the silver, as copper, lead, nickel, and zinc, with cobalt, and a variety of earthy minerals. In the department of the Puy-de-Dôme, the proportion of silver to the lead ore is 400 grammes to 100 kilogrammes. The lead ores of Brittany, as well as those of other mining districts, contain, as I have said, more or less silver.

SPAIN is an old silver-producing country. The metal is not found alone so much as associated with lead. The strata and the lodes in which the latter occurs will be described under the head of that metal. According to Strabo, 40,000 men were formerly employed at the mines of Carthagena, and the daily returns of silver amounted to 20,000 drachmas (8¾*d.*), or 911*l.* 7*s.* sterling. In 1839 a lode of argentiferous galena was discovered in the same neighbourhood, which gave 1,800 arrobas,[1] or about 20 tons of lead ore per day. The lead ores of the Sierra de Gador only give 2 ounces of silver to the ton. The galena of

[1] 1 arroba = 25 lbs.

Linares, in the province of Jaen, gives about 9 ounces to the ton. The galena of the Jaroso vein of the Sierra de Almagrera, between Carthagena and Almeria, is exceedingly rich in silver, yielding as much as 130 to 180 ounces to the ton; while that of the lead ores of Hornachos are said to give 100 ounces to the ton. The silver is most abundant in the upper decomposed parts of the lodes, where it is combined with sulphate of lead and the hydrated oxide of iron.

As a rule the lead from the slaty rocks of Spain is richer in silver than that derived from the limestones. The total annual production of silver in Spain may be estimated at 120,000 lbs.

NORWAY.—We have retraced our steps eastward somewhat in visiting Spain, and now we must take a long stride to the north-west margin of Europe, where, in the south of Norway, we find the most celebrated silver mine of Europe, that of

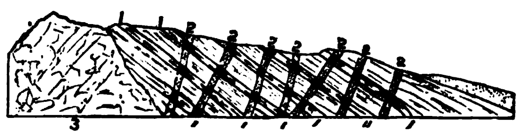


FIG. 38.—DIAGRAM OF THE SILVER FAHLBANDS AT KONGSBERG, NORWAY.
1 1 1 1, Fahlbands in gneissose and micaceous slates. 2 2 2 2, Veins. Dark shadings rich ores. 3, Gneiss.

Kongsberg. It was discovered in the year 1623, and, with the exception of a few intervals, it has been worked until now. The ore occurs at this mine, as will be seen by a reference to fig. 38, not so much in true lodes, as in a succession of layers of partly decomposed rock, known as 'fahlbands,' or 'rotten belts,' 1 1 1 of section. There are seven of these layers interstratified with gneissic and slaty rocks, and with which, in structure, they have much in common. They have been found productive of silver over a length of several miles, and a breadth of about a thousand feet. The ore is finely disseminated throughout the layers, but not in sufficient quantities to pay for mining in the rocks themselves. These decomposed beds are, however, as well as the adjacent strata, traversed by true veins also con-

taining silver ores, and the profitable deposits of ore lie at the junction of the veins with the fahlbands; the veins as well as the beds being too poor to work alone at a distance from the points of intersection. The total yield of silver in Norway may be estimated at 20,000 lbs. troy. Silver is also derived from the lead ores of both NORWAY and SWEDEN.

GREAT BRITAIN.—We now cross over to the British Isles, in which, although there is not a single silver mine proper, the production of this metal amounted in 1876 to 483,422 ounces,[1] to which if we add the production of several mines which did not specify the amount of silver obtained, the quantity will be brought up to 500,000 ounces. This amount was obtained from 80,000 tons of lead, so that the proportion of silver to the ton of ore was 6¼ ounces. The lead itself, as we shall see, is derived from two different geological formations: 1st, the slates of the Llandeilo beds of the Cambro-Silurian strata, and, 2nd, the beds of the Carboniferous limestone. The mines worked in the former and older rocks, as in Spain, gave the largest percentage of silver. Of individual mines from this formation we find the highest yield of silver from Great Laxey Lead Mine in the Isle of Man, where 2,500 tons of ore gave 103,332 ounces of silver, or over 40 ounces to the ton. Foxdale Mine, in the same island, gave a nearly equal proportion. West Chiverton (see fig. 87), in Cornwall, was the next best, giving 29,925 ounces of silver to 1,594 tons of ore, or about 18 ounces to the ton. In Devonshire, the Frank Mills Mine gave 14 ounces to the ton. The average of the mines in Shropshire was 6 ounces, of Cardigan 7½ ounces, and of Montgomery 8½ ounces. The silver from the latter county came chiefly from the Van Lead Mine, near Llanidloes (see fig. 83).

Turning to the mines worked in the Carboniferous limestone, the percentage of silver to the ton of ore was 3 ounces in Northumberland and Durham, 4½ ounces in Westmoreland, 2 ounces in Yorkshire, 5 ounces in Flintshire, and 4 ounces in Denbighshire. The limestones of Derbyshire are not reported as yielding any silver. Single mines in the limestone have

[1] Hunt, *Mineral Statistics of Great Britain and Ireland.*

made large returns of silver, thus from some of the ores of Alston Moor as much as 80 ounces to the ton of ore has been obtained.

In Cornwall,[1] about Liskeard, galena has been found most productive of silver when it has been mixed with a little copper, and when this mixture took place in clay slate there was often a yield of 16 ounces of silver to the ton. Silver is also there more abundant in hard than in soft strata. The cross veins of that county do not usually contain much metallic mineral, but in some mines, at a depth of about 100 fathoms, some profitable bunches of vitreous silver enclosing crystals of galena have been found. At Wheal Ludcot crystalline grains of both vitreous and ruby silver with flakes and threads of native silver have been found. At Herodsfoot Mine, at a depth of 127 fathoms, when the galena has been found of large grains it has not usually been rich in silver; but on changing into a fine grained ore in a brecciated lode, it has become highly argentiferous. The same result has been found to occur under similar conditions in the lode at Goginan in Cardiganshire. The metal is found associated with the copper and lead ore, known as bluestone, at Morfa Ddu, in Anglesea; and in County Wicklow, Ireland, it has been observed disseminated in a bed of brown oxide of iron. A description of some of the chief silver lead-producing mines of the British Isles is given in the chapters treating of lead ores.

The total production of silver from 77,350 tons of lead ore raised in the British Islands in 1878 was 397,471 ounces, or about 6¾ ounces to the ton of ore.

Last year 27 tons 19 cwt. of silver ore were raised.

[1] De la Bêche, *Geological Report on Cornwall;* Henwood, *Metalliferous Deposits.*

CHAPTER XII.

SILVER—continued.

Silver Ores of North-Eastern America—North-Western America—The Comstock Lode and Ruby Hill, Nevada—The Emma Mine, Utah—Similarity of the Deposits northwards and southwards.

NORTH AMERICA, *Eastern.*—Crossing again to the North American continent we find that in its eastern half the silver produced is obtained, as in Britain, chiefly from the ores of lead. This is more or less true of the lead mines from New Brunswick southwards, and the same remark may be made of the lead region of the Upper Mississippi and Missouri, so that there is nothing in its occurrence in these regions to require special notices.

NORTH AMERICA, *Western.*—It is in western North America that silver mining has of late years attained a magnitude and importance unprecedented in the history of mining.

Following the gold in the driftal deposits to its source in the quartz beds and dykes amid the peaks of the Rocky Mountains, the miners were for a long time intent upon finding the auriferous metal alone. During this period they cast aside with the common metals a blue-looking substance that was more than usually abundant. The discovery of known silver ores by two gold washers, who were digging a little reservoir for their use, near the site of the town of Gold Hill, drew general attention to this mineral, so that now the number of silver mines in the Western States is legion. The quantity of silver raised last year amounted in value to the large sum of 9,000,000*l.*, which was distributed over the various States as follows :

Arizona	$1,000,000
California	4,825,000
Colorado	3,600,000
Idaho	1,000,000
Nevada	31,000,000
Other States, as Utah, Dakota, Montana, New Mexico, Oregon and Washington, and Wyoming	4,650,000
	$46,075,000

or about 9,000,000*l.* sterling.

It will, I think, afford my readers a fair idea of the various ways in which silver ores are found deposited in western North America if I select from the above States three lodes or groups of mines, each of which besides being the representative of a mode of deposition, is also for other reasons familiar by name to most of them. These are: the Great Comstock Lode of Nevada, the Eureka Deposits of Eastern Nevada, and the Emma Mine of Utah.

Usually, the Great Comstock lode[1] is considered a fissure vein. It nevertheless occurs at the junction of two dissimilar formations, and it may therefore be a mineralised bed. It runs roughly north and south along the eastern slope of a range of hills that course parallel to the great Sierra Nevada range, at a distance of about fifteen miles to the east. It may be found on a map south of the Central Pacific Railway, between the lakes Bigler and Carson. The lode has been followed for over four miles in length, and about thirty-five mines have been opened along its course, the most successful of them being known as the great 'Bonanza' mines. The Sutro Tunnel, which has been in progress nearly ten years, struck the lode in the Savage Mine in 1879, and when the branches north and south (shown on fig. 40) are completed, the whole of the mines can be drained to a depth of 2,200 feet, from the outcrop of the lode on the side of Mount Davidson. The width of the lode varies from 100 to

[1] Raymond, 'Mining Statistics west of the Rocky Mountains,' *Engineering and Mining Journal*, New York, May 1878; Sutro, *The Sutro Tunnel to the Comstock Lode.*

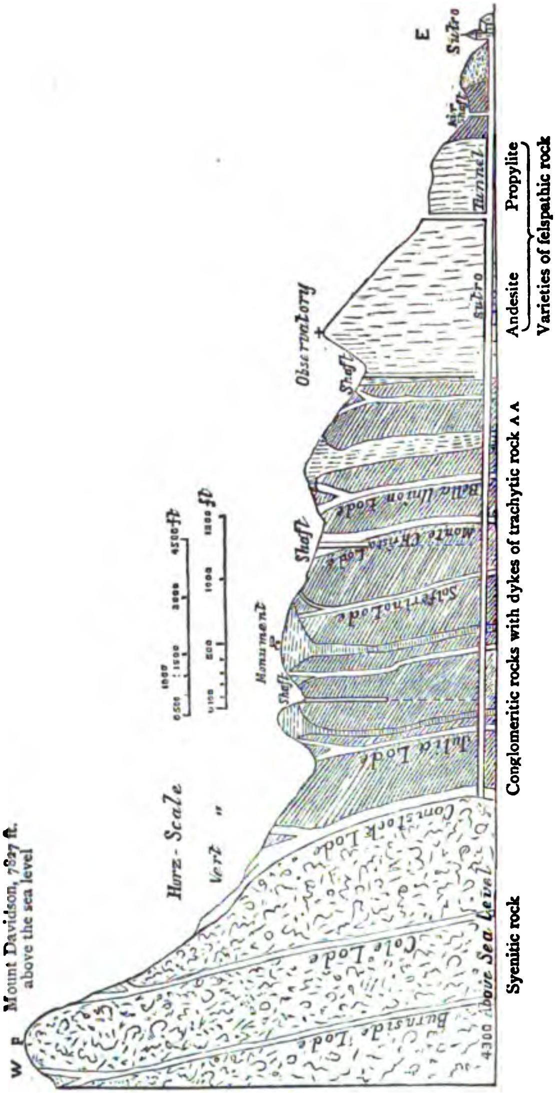


FIG. 39.—SECTION ACROSS THE COMSTOCK LODE AND STRATA.

200 feet, and it dips eastward at an angle of 45 degrees from the horizon. Its course and dip follow, as I have said, generally those of the strata by which it is bounded. A reference to fig. 39 will show that it lies between syenite below, and talcose and metamorphic slaty rock above. The latter rock contains felspathic dykes, and it is interstratified by felspathic beds. The syenite and possibly the immediately overlying slaty rocks may correspond to similar silver-bearing strata of Llandeilo age in our own country. The overlying strata with their volcanic dykes and lavas being apparently of tertiary age.

Generally speaking the non-metallic contents of the lode consist chiefly of quartz, fluorspar, chlorine, and sulphur, throughout which are disseminated gold and silver in the proportion of about one-third gold and two-thirds silver. But little antimony is found with the silver.

The lode is not uniformly rich throughout, as

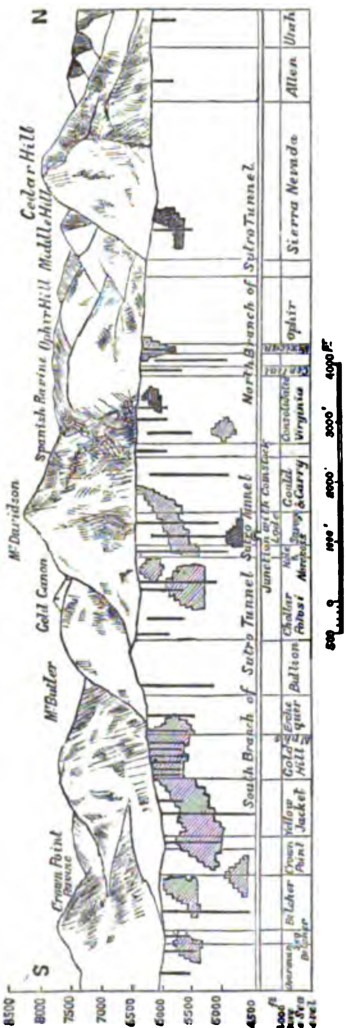


Fig. 40.—The Comstock Lode. Longitudinal Section showing the Depths and Workings of the Different Mines, &c.

will be inferred from the segregation of the ore into great ore bodies, as shown in the longitudinal section, fig. 40. Starting on the north of the section, and passing by the scattered ores of the Utah and Alten mines, we find four chief ore bodies between the Utah and the Chollar Potosi, a distance of over 12,000 feet. The first of these ore bodies in the Sierra Nevada ground contains gold and silver to the value of from 1*l.* to 2*l.* per ton, besides which it has low grade ores of the value of from 12*s.* to 30*s.* per ton, which at present hardly pay for working. The ground has been explored to a depth of 600 feet below this ore deposit, but has proved barren. Between this and the next ore body, in the Ophir and Mexican claims, is a stretch of 1,600 feet of comparatively barren ground. This second ore body is partly exhausted of its rich ores, of which it has yielded immense quantities. A large quantity of low grade ores remain, which cannot now be profitably worked. At a depth of about 700 feet, the lode was pinched and partly filled by porphyries, the quartz disappearing; but an ore body lies at a greater depth in the Consolidated Virginia Mine. The next ore-body starts in Gould and Curry's ground; it is over 2,000 feet in length and 1,000 feet in depth. This, the Potosi Chimney, has been one of the richest deposits, and has yielded about 3,000,000*l.* Its rich ores were extracted at the rate of 650 tons a day, at a value ranging from 17*l.* to 25*l.* per ton of ore. It ran out in depth into a quartzose rock, six feet wide, mixed with clayey matter. A similar deposit to the last occurs in the Chollar Potosi mine. Latterly a lower ore deposit has been struck in the Hall and Norcross Mine, at a depth of 1,100 feet. It has been laid bare for 260 feet, and it is from six feet to thirty feet wide. Its ores differ from those on the higher levels in containing more galena, copper, iron, and blende. They average 6*l.* per ton, although selected parcels have made 13*l.* per ton. The richer portions are irregularly distributed through the thirty feet of quartz lode, portions of the latter from fifteen to twenty feet square only yielding 5*l.* to the ton. The shaft of the next mine, the Savage, has reached a depth of 2,300 feet, and it is this mine which the Sutro Tunnel has just

entered. At a depth of 1,000 feet it entered the ore body just described.

Below the Chollar Potosi deposit, at a depth of 800 to 1,200 feet, the lode was partly filled with porphyries, with occasional thin quartz seams, containing only traces of ore. It had a large quantity of ore, varying in value from 3*l.* to 5*l.* per ton.

Another great ore body extends from the Exchequer to the Crown Point. From this also most of the rich ores have been extracted, leaving a large quantity of the value of from 2*l.* to 3*l.* per ton. In the various mines on this part of the lode, at depths ranging from 1,100 to 1,500 feet, the lode expands to about 90 feet in width, made up largely of porphyry and compact quartz, containing small quantities of the sulphides of lead and zinc, with only traces of silver. These metallic ores were found in quartz seams on each side of the lode, the middle of which for a great thickness was filled up with barren porphyry. As a rule the more compact the quartz the less productive, and the more sugary it becomes the more largely it is charged with metallic ores. It will be observed that there is a deeper ore body in the Belcher and Crown Point claims. Thus far these deeper ore bodies have not been so rich or so large in metals as the higher ones; the matrix also contains more carbonate and sulphate of lime. It becomes a serious question whether the productive character of the lode has ceased in depth, or whether, as in the case of the Chanaracillo Mine, fig. 44, the lode is only temporarily pinched by passing through porphyry and calcareous ash. It is much feared that the former is the case. Explorations will, however, be aided by the deep tunnel now made. The mines will be drained, and the low grade ores, of which large quantities remain, may be mined more cheaply.

The estimated value of the yield of the Comstock lode for some years has been 3,500,000*l.*, and its total yield since its discovery in the year 1859, 70,000,000*l.* sterling.

The country adjacent to the Comstock lode is reticulated with lodes and veins. Some of the chief of these are shown on the section, fig. 39. In the Flowery district the Lady Bryan Mine is worked at surface, near 300 feet wide. Native silver

has been found in it, and fine sulphides yielding the value of 9*l.* to the ton of ore. The Monte Cristo lode has also yielded in places large returns.

The town of Eureka,[1] which has grown up within the mines of the district, is situated in the eastern part of the State of Nevada, 91 miles south of Palisade station, on the Central Pacific Railway, with which it is connected by a narrow gauge railway—the district surrounding, which is traversed by the mineralised strata now to be described, forms a range of hills that lie between the ridge containing the Comstock lode and

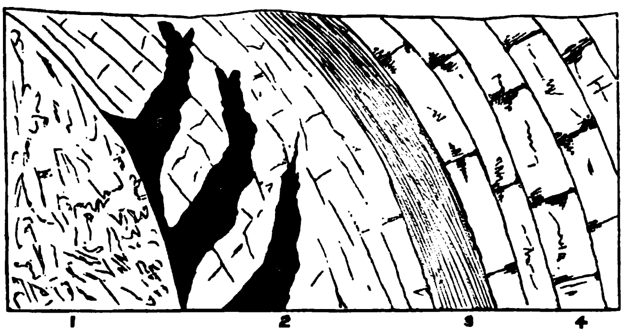


FIG. 41.—STRUCTURE OF RUBY HILL, EASTERN NEVADA, SHOWING MINERALISED LIMESTONE BEDS.

1″ = 200 ft.

1, Quartzites. 2, Mineralised limestone beds. 3, Shales. 4, Dolomitic limestones. 5, Ore deposits.

the Wahsatch range of mountains, in which the Emma Mine with others is situated. Indeed, the country intervening between the Comstock and the Emma is traversed from north to south by several similar chains of hills, some of which are so highly mineralised as to have given to Nevada the name of the Silver State.

Silver Hill, Prospect Mountain, and Ruby Hill are parts of such a range of hills which lies immediately to the west of the town of Eureka. They contain at present about sixty distinct

[1] *Engineering and Mining Journal of New York*, December 1877, January 1878.

silver mines. The metal was first discovered here in the year 1864 by a party of miners, on their way to White Pine. Some 'laggards' of the party, seeking an easier road, saw some rich mineral 'float' in what is now known as New York Cañon. They quickly made locations, but little was done until the year 1869, when a small furnace was set up. Later, the Eureka Consolidated Mining Company was formed out of several small mining setts, and more recently the Richmond Consolidated out of a number of others.

The diagram, fig. 41, illustrates the structure of Ruby Hill, on which these great mines are situated. 1 consists of granites, quartzose slates, and metamorphic rocks of great thickness. 2 is a belt of limestone, 300 feet thick. Judging from the fossils found in it, it is of Cambro-Silurian age, and it contains segregations of ore. It is surmounted by calcareous shales, 3, and these by higher limestones, possibly of Carboniferous age, and which form a belt of great thickness.

The mineralised belt of limestone, 3, is, where unaltered, dolomitic in character, containing from 34 to 46 per cent. of carbonate of magnesia. It also varies from 1 to 2 per cent. of oxide of iron. Where bedding is apparent, as in the Phœnix Mine, it is conformable to the rest of the stratification, but for the most part the bedding is not discernible, owing to the phenomena now to be described.

The limestone, 2, has been greatly crushed and shattered, and within the mine workings it may be seen, now broken up into great masses, then roughly crumbled into small fragments, and again, especially where it is of a sandy nature, ground into fine powder. The shattered fragments have for the most part been recemented by calcareous matter, and form a hardened mass. The sandy portions of the limestone are often dangerous, because of their tendency to run in. In the midst of these reconstructed limestone beds huge caverns (*ore chambers*) are found, the sides and roofs of which are lined with stalactite and crystals of arragonite, while the floors are covered to a greater or less depth with metallic ores. These caverns are due to chemical action, aided by mechanical causes. In other words,

the carbonate of lime has been dissolved out of the mass by the infiltration of water, the passage of which has been rendered easy by the cracks and gaps left in the shattered limestone.

The first ore cavity found was on the site of the Champion Mine, and it lay below a spot where ore was found on the surface. Below this cavity, at a depth of about 300 feet from the surface, a larger cavern has only recently been discovered.

Besides these irregular cavities, the limestone is traversed by two main systems of fissures, one running parallel to the strike, and another at right angles across the beds. These last are nearly vertical, and at the points where they strike the underlying quartzite, which they do not enter, ore deposits are usually found. The ore deposits have a general tendency towards the dip of the beds. They start high up in the limestone, as shown in fig. 41, and expand downwards towards the rock below. Near the points of junction the richest ores occur, the lower grade ranging around the sides of the deposits. In the Eureka Mine one of these deposits has been followed 200 feet along the strike, and 160 feet down the dip of the quartzite rock, and another body has been worked for 300 feet along the face of the bed. The face of this quartzose rock is somewhat undulatory, so that the ore is found filling the depressions in it, and occasionally passing over the upward curve from one hollow to the next.

The ores consist chiefly of carbonate of lead largely mixed with ferruginous matter. The best quality is that known among the miners as black carbonate. This contains from 60 to 70 per cent. of lead, with gold and silver ranging in value from 20*l.* to 40*l.* to the ton of 2,000 lbs. The ordinary ores contain from 16 to 20 per cent. of lead, with gold and silver valued at from 8*l.* to 15*l.* per ton. Besides these ores, there is an abundance of still lower grade ores found especially in depth, which with the present cost of mining and transport are neglected.

In the third level of the K K mine, a huge mass of quartz was found in one of the ore chambers. It was 90 feet long, 45 feet wide, and 25 feet thick. It was of a sugary texture, and was probably formed *in situ* by the filtration of water

charged with silica. It did not hold much lead, but it was rich in gold and silver, valued at from 5*l.* to 35*l.* per ton.

The general phenomena of this Ruby Hill limestone and its contained minerals, seem to indicate that the latter have been accumulated by the percolation of water charged with the various minerals from the overlying or adjacent older strata. The farther downward progress of this has been stopped by the unbroken quartzite and the ore largely arrested there. The crushed character of this mass of limestone, 2, seems to die out downward; the overlying solid limestone beds and strata approaching the quartzite in depth. It is therefore a V-shaped portion of the lower part of the great limestone zone, crushed and broken between the beds above and below, and thus made a fitting depository for the ores once disseminated throughout the entire mass, which have been added to the richer ores that, possibly prior to the deposition of the limestones, had accumulated in the hollows of the quartzite rock.

The Emma Mine, apart from the unenviable notoriety it has gained by litigation, will serve my purpose in illustrating a deposit of silver ore under different geological conditions to those of the Comstock and Eureka, or Ruby Hill deposits, and it may be taken as the representative of the group of mines with which it is associated—the Flagstaff, Silver Star, Exchequer, and others.

The Emma Mine[1] is situated, along with the other mines just named, in the Wahsatch range of mountains, the higher peaks of which rise 12,000 feet above the sea level. The range courses north and south, about twenty miles east of the Great Salt Lake, and it forms a parallel ridge of similar structure to the main chain of the Sierra Nevada. Numerous streams come leaping and tumbling down the deep cañons that furrow the side of the range, and flow into the Salt Lake. It is up the most southerly of these, the Little Cottonwood Creek, about twenty miles SE. of the lake that the Emma and other mines are worked.

[1] A. C. Peale, *United States Geological Survey*, 1873; R. W. Raymond, *Report on the Emma Mine*, 1872.

Ascending from Salt Lake City to the higher parts of the range up this creek, we have a grand natural section of the geological structure of the country. Near the mouth of the creek, on the west, great granite peaks covered with snow rise on either side. The granite is in massive beds that dip at an angle of from 50 to 70 degrees to the east. The granite is of a light grey colour, and is composed of white felspar, quartz, and black mica. It is of this granite that the Mormon Temple of Utah

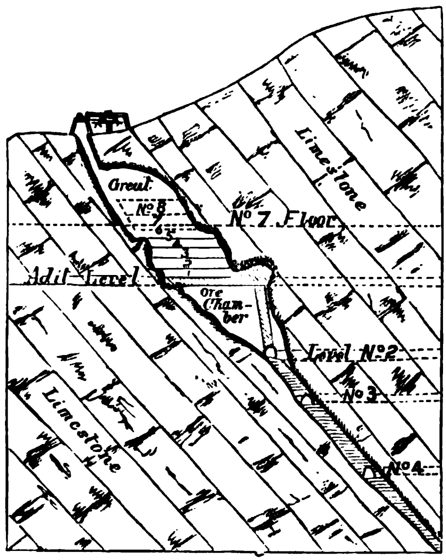


FIG. 42.—TRANSVERSE SECTION OF THE GREAT ORE CHAMBER AT THE EMMA MINE. 1″ = 159 ft.

is built. This continues for five or six miles up an ascent of 500 feet to the mile, then the granites are seen overlaid by quartzites of a reddish colour. These are succeeded by a series of slates, upon which rest thick beds of white limestone, supposed to be Cambro-Silurian. The passage of these into the Carboniferous group is rapid, massive dolomitic limestones of Carboniferous age being seen resting upon the greatly older

limestone beds. It is in these Carboniferous limestones that the ore deposits are here found, and the Emma and associated mines worked. Fig. 42 represents a transverse section through the great ore chamber of the mine, from which it will be seen that the ore masses correspond roughly to the line of bedding. Underneath and above the ore horizon there are beds of white dolomitic limestones. Between these, there is a thickness of about 250 feet, which seems to mark the limits of the ore horizon. In this zone are great irregular masses of brecciated limestone that contain spots and lumps of galena, and patches of soft earthy ore. Following roughly the lines of bedding, are great segregations of metallic ores, like those taken out of the chamber shown in the figure. These metallic ore deposits seem to be confined to the upper and lower sides of this mineralised zone, the levels that have been driven across it not having apparently struck any ore chambers in the middle part of it. The repetition of these ore chambers will probably be found along the course of the beds at these horizons, and down the dip.

The character of the orey matter from these deposits will be gathered from the following analysis by Mr. James P. Merry, of Swansea, of an average sample of 82 tons of first-class ore:

	Per cent.
Silica	40·90
Lead	34·14
Sulphur	2·27
Antimony	2·27
Copper	0·83
Zinc	2·92
Manganese	0·15
Iron	3·54
Silver	0·48
Alumina	0·35
Magnesia	0·25
Lime	0·72
Carbonic acid	1·50
	90·42
Oxygen and water by difference	9·58
	100·00

The quantity of silver actually obtained from this consignment of 82 tons, was 156 ounces to the ton of 2,240 lbs. The second class ores yield about 25 ounces of silver to the ton. The absence of lime from this orey matter in the midst of limestone is remarkable.

The section, fig. 42, shows the size of the ore chamber under Woodman's or Discovery shaft. Further to the south-east, under the Emma shaft, it is not of such large dimensions. It has only been explored at this mine for a length of about 300 feet. But the recurrence of similar segregations has been proved in neighbouring mines, and, judging from the latest reports, in the Emma Mine itself, which we are told is being worked to a profit by the original American owners, while the English shareholders are engaged in litigation.

Still farther to the north-east mining for silver lead is progressing in the upper reaches of the rivers that form the Missouri, but nothing of practical or scientific interest can be added to the description just given of mines in the same strata in Nevada and Utah.

Occurring in or near the older rocks, as in the Comstock lode and in the quartz portions of the Ruby Hill deposits, silver is found as ores which may be separated by washing and mechanical action, and are known as free milling ores. As found in the limestones at Ruby Hill, and those of the Wahsatch mountains, the silver is chemically blended with lead and other metals, and the ore therefore requires to be smelted.

If the reader will now take a map of western North America, and follow the line of these three mineral deposits south-easterly into New Mexico, Arizona, and Mexico, he will have in the three descriptions I have just given the explanation of the chief modes of the occurrence of silver ores in those regions.

CHAPTER XIII.

SILVER—continued.

Silver in Arizona—Mexico—The South American Continent—Peru—Bolivia—Chili—Western side of South America generally—Concluding Observations and Deductions.

IN ARIZONA the lodes follow the stratification and extend for miles. Those of the Globe district correspond to the class of which the Comstock lode, described in the preceding chapter, belongs. They are composed of quartz, crystallised felspar, yellow spar, and limestone, the metallic ores, chloride of silver, and native silver, with sulphides and silver glance, besides which they carry subsidiarily antimony, arsenic, copper, and galena. This State has only been lately opened up as a mineral country, although its rich mineral character was previously known.

MEXICO was formerly famous for its silver mines, and probably under Anglo-Saxon management it may become famous in the future. We find two distinct classes of deposits in this region: first, those of the old rich mines of Pachuca real del Monte and Moran, which occur, like the Comstock, between porphyritic and slaty rocks; and secondly, those of Real de Calorce and the mines near Zimapan, that occur in limestone, like those of the Wahsatch range, the lodes running up into even higher limestones. In both Arizona and Mexico there occur large quantities of native silver, which some have thought have been naturally smelted from the ores by volcanic heat.[1] We now pass rapidly southwards to the South American continent, and passing by the mines of Central America, Venezuela,

[1] H. S. Jacob's Report, *Mining Journal*, 1877.

and New Granada, which are of increasing importance, we will at once notice the silver mines of Peru and the countries lying to the south.

PERU.—The name of Peru is closely associated with the idea of silver wealth. The great chain of the Andes, as it courses down western South America, maintains the same geological structure as that prevailing in the Rocky Mountains of western North America, and the silver lodes occur under similar conditions in both continents.

The principal silver mines of Peru are those grouped about Yauricocha or Pasco, about half-way down Peru. These were accidentally discovered in the year 1630.

The neighbourhood contains a variety of silver deposits,

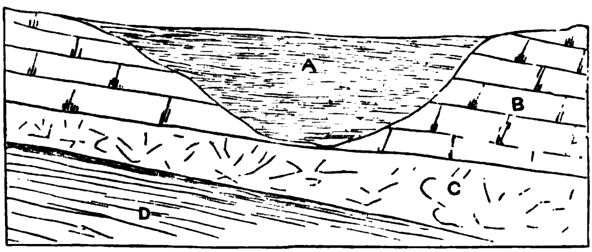


FIG. 43.—ARGENTIFEROUS STRATA, SANTA ROSA MINE, PERU.
A, Beds charged with silver ores. B, Limestone. C, Silt or porphyry. D, Shales.

the relationship sustained by each to the other being only imperfectly understood scientifically. There are two principal silver lodes or horizons of strata, named respectively Veta de Colquirica and Veta de Pariarica. The first of these has a direct north and south course, known for two miles with a breadth or thickness of 400 feet. The second runs from WNW. to ESE., and crosses the first under the market-place of the town of Pasco.[1] Besides these there are in the district, as at the Santa Rosa Mine, argentiferous beds like those of Norway, fig. 38, only richer.

Mr. Rutter, of Camborne,[2] describes a series of such beds, of which fig. 43 may be taken as an illustration.

[1] 13,673 feet above the sea. [2] *Mining Journal*, September 8, 1877.

A represents a flat mass of mineralised rock composed of gossan, iron quartz, and pyrites. It lies in a basin-shaped hollow in limestone and sandstone rocks, which is about three-quarters of a mile in diameter. Where the deposit abuts against or graduates into the limestone, small veins containing lead ore are observable; but they do not seem to have any relation to the silver ores of the deposit. At 148 yards from the surface a shaft that was sunk passed through the deposit, and entered a grey-spotted porphyritic rock, which lay upon a bed of silt, containing fragments of limestone. It is a pity this shaft was not sunk deeper.

The details of the geological structure of the country are not clearly made out, and it may be that one of the two great lodes described above may be a mineralised series of beds—probably the north and south one. The deposits have been generally supposed to have become poorer in depth, which, if they are beds or segregations of metallic ore, is reasonable to expect; but if they are really lodes of great width, there may be only a local deterioration, as in the case of the Chanaracillo lode, to be described: but the deep tunnel about to be driven by Mr. Meiggs,[1] who has done much for the development of Peru, will solve the problem.

At Hucantajaya, nine English miles from Aquique, there is a radiation of nearly vertical lodes from a common centre, and these are crossed by smaller veins, containing silver. The hill Aquique, from which these lodes radiate, is composed in its upper portion, and to a depth of 70 yards, of a conglomerate of medium-sized stones, set in calcareous matter. In this conglomerate the prevailing ore is a chloride of silver. Lower down the ores change to sulphides.

At Santa Rosa and Huantaca, near Aquique, silver is associated with nickel and copper ores, which are more abundant than at Huantajaya, where the amount of copper is reduced to about 4 per cent. of the metallic ores.

Heretofore the mines of this district have been very carelessly worked, so much so that only the most prolific mines

[1] Since the above was written Mr. Meiggs has died.

could pay for working. The total yearly yield of the country may be taken at 300,000 lbs.

BOLIVIA.—Following the Andes southward into Bolivia, we reach, about lat. 19° S. and long. 65° W., the famous silver mines of Potosi. These were discovered in the year 1545. They are worked in the isolated mountain of Potocchi, which rises 16,000 feet above the sea. It is traversed by thirty-two principal lodes, as well as by a number of smaller veins, which form a network in the older rocks of which the mountain is composed. The amount of silver yielded by these mines since their discovery may be estimated at 300,000,000*l.*, or about one million sterling a year, besides the ore that has been wasted by the reckless way of working. The mines have been worked to a depth of about 1,000 yards. The proportion of silver ore is reckoned at 1 ounce fine silver to 1 lb. of ore. Peru and Bolivia, taken together, contain about four hundred abandoned mines, many of which with proper appliances and skilful management might doubtless be profitably worked.

CHILI.—Still following the Andes southward, we come to the well-ordered Republic of Chili, whose mines are better worked, and are very numerous and productive. It may be observed here, generally, of Chili, that its mines have been grouped into four districts, which are distinguished from each other by the presence of various metals associated with silver ores, and the variation in the ores of that metal.[1]

Starting on the north, there are first the mines of the mountains north of the valley Huasco, which are richest in silver, but which also contain gold and copper. Secondly, there is the district between Huasco and Coquimbo, in which are numerous veins of pyritous copper, and between Arqueros and Arquaamaza, chloride of silver and native silver. Thirdly, there is the district between the valleys of Coquimbo and Aconcagua, where in granitic rocks gold-bearing veins are common; and, fourthly, there is the district south of Aconcagua, where we find granites filled with auriferous lodes, and mines of silver

[1] See also Whitney, *Metallic Wealth;* and Henwood, *Metalliferous Deposits.*

Nature of Lode.

Thin veins of sulphuret of silver

Flakes of native silver and chloride of silver in joints of limestone near the vein

Seven to thirty lbs. of silver to the ton of ore

Sixty lbs. of silver to the ton

From the depression in the greenstone ore to the value of 800 lbs. of silver to the ton was obtained

No silver in the vein as it passes through the porphyritic rock

Large deposits of ore rich in silver, 40 lbs. of silver to the ton of ore. Lode melts into limestone

No silver ore

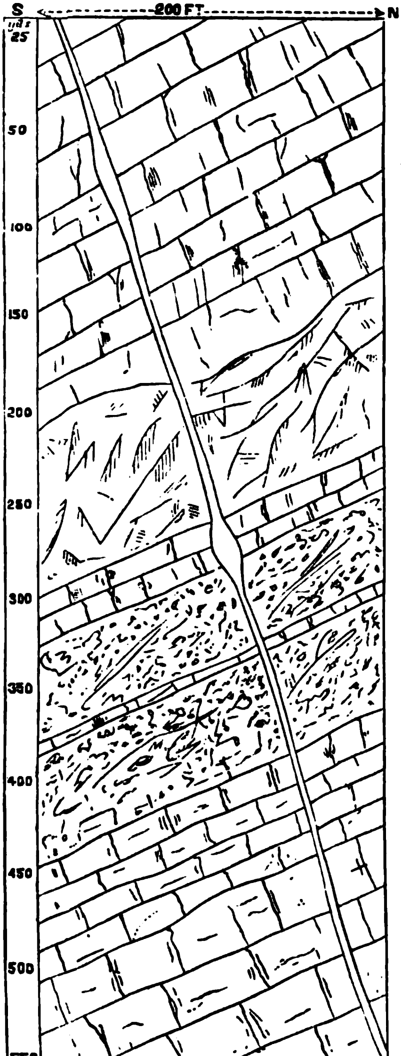
A little silver ore in the thin limestone

No silver ore

Iodide of silver

Sulphuret of silver $1\frac{1}{3}$ lbs. to the ton of ore

Section



Strata

Beds of brown, blue, and buff cellular limestone, containing grey silver ore and chlorides of silver filling its joints, native silver in crevices near the lode

Fine blue limestone, with arsenical pyrites

Flinty limestone

Arenaceous ditto
Greenish-grey ditto

Dark blue compact limestone

Porphyritic and hornblendic rock, traversed by veins of quartz

Fine-grained dark and grey limestone
Dark yields silver-grey, barren

Greenstone rock, with veins of calcareous spar, thin bed of argillaceous limestone in centre

Gradual passage into limestone below

Beds of blue, grey, and greenish-grey limestones, with irregular deposits and thin veins of calcareous spar, and lines and spots of chlorite and asbestos

FIG. 44.—SECTION OF STRATA AND DESCRIPTION OF THE PRINCIPAL LODE AT CHANARACILLO, NEAR COPIAPO, IN CHILI.

and argentiferous copper worked in the stratified rocks overlying the granites along the summits of the Andes.

We may take the neighbourhood of Copiapo in the first of these groups as a representative one of Chili, and a description of the old Chanaracillo Mine will serve to illustrate the usual mode of the occurrence of silver ores in true fissure lodes in older limestone.

This lode was discovered in the year 1831, and up to 1853 the mine had yielded 2,035,424 lbs. of silver.

Fig. 44 represents to scale the size of the lode, and the variations in the strata through which it passes; annexed to it there is also a description of the strata, with the particular features and composition of the lode at the various depths given. The limestone is probably of the same age as the silver-bearing limestones of Nevada, and both probably correspond to the lower part of the limestones overlying the gold deposits of Gongo Soco, fig. 21, on the eastern side of the continent. The limestone beds dip to the south-west, and the lode dips in a contrary direction. The earthy matter of the lode partakes largely of the nature of the strata it passes through, being partly filled with disintegrated fragments of the adjoining rock. It is destitute of silver as it passes through the greenstone, but is most productive in the limestones at their junction with the upper surface of that rock. The limestones themselves are charged with silver in grains and dust throughout their mass; the ordinary joints are charged with silver ores, and in the joints near the lode there is much native silver. At these points, where the joints open upon the lode, the walls of the latter are not well defined, the lode and the limestones gradually changing into each other. In 1856, the silver derived from each ton of ore was 466 ounces troy, the total production of the mines that year being 115,656 ounces. Within this quantity, the vitreous red and rarer ores yielded from 90 to 100 ounces per ton.

All down the western side of the South American continent, chloride of silver is the common ore, which is to be expected in a country so abounding in deposits of saline matter. As a rule

93 per cent. of chloride of silver ore makes 70 per cent. of metallic silver. Where much antimony is present, as in ruby silver, the separation of metallic silver from the ore is somewhat difficult.

Such are the principal silver deposits of the world. It is probable that in a few years Australasia will take her place as a silver-producing continent. Already, in 1876, New South Wales produced 69,179 ounces of silver, of the value of 15,456*l.*, and Victoria in the same year yielded 26,356 ounces, nearly the whole of which was separated from the gold melted at the Mint. In 1879 the silver derived in the same way amounted to 23,729 oz. 15 dwt.

From the foregoing description it will be seen that silver occurs at two distinct and separate geological horizons. First, at the junction of the Cambrian with the Cambro-Silurian groups of rocks, in slates and calcareous strata; and, secondly, in the Carboniferous limestones. Of the first horizon it may be said that, in the lower part of it, probably down in the Cambrian strata where limestones are absent, silver ores are mixed with metallic gold, and both are separable by mechanical means from their admixtures. In the limestones and upper portions of the group in the Llandeilo slates, they are chemically blended with other metals and need smelting. The same is true in a greater degree of the higher group—the Carboniferous limestone. The favourite metallic associate and repository of silver is lead, and it is contained in a larger proportion in this metal when both metals are found in the slates and shales of the older rocks than in the newer limestone: the proportion of silver in lead ores apparently decreasing with the deposition of the newer limestones. The presence of silver in lodes or strata is not usual in beds newer than the Carboniferous limestone, although in Peru Coal-measures rest immediately upon limestones charged with silver; and in the Banat, in Austro-Hungary, a much newer limestone of the Cretaceous period rests immediately upon metallic deposits formed on the surfaces of a vastly older rock; and in the Comstock lode very recent strata lie not far above the lode or bed.

CHAPTER XIV.

COPPER.

General Remarks—Native Copper—The Ores of Copper.

ALTHOUGH not so costly, copper can hardly be said to be less valuable than either of the two noble metals already described. Its numerous applications to the uses and purposes of life are already familiar to my readers, and I need not, therefore, enumerate them, but proceed at once to describe the principal forms and ways in which it occurs in nature.

Copper is found native, as in the mines of Lake Superior, and also in various combinations with acids, as well as with oxygen, sulphur, and other substances. The ores range about 4 in hardness, and from 3·5 to 8·5 in specific gravity; the latter being that of native copper, and the former that of the ordinary carbonates.

NATIVE COPPER.—This is found more or less in most mines associated with the ores. It occurs in lumps of all sizes up to great masses of many tons weight. A mass taken out of the Cliff Mine, described further on, measured 40 feet long, 6 feet deep, and 6 inches thick; its weight was estimated at 200 tons. Silver is, as we have seen, usually intimately mixed with native copper, but is also in distinct specks, flakes, and crystals in the metal, as if, in the process of cooling, each metal had gathered itself together and had solidified separately.

The principal ores of copper are the following:

COPPER GLANCE (*Redruthite*).—Composed of 79·8 of copper and 20·2 of sulphur, with sometimes 1 to 2 per cent. of iron replacing a portion of either mineral. Its hardness is from 2·5 to 3, and its gravity 5·5 to 5·8.

This ore comprises the following varieties :

Blue Copper, also named Covelline and Kupferindig.—Composition : 66·7 copper and 33·3 sulphur.

Digenite.—Composition : 70·20 copper, 29·56 silver, and 0·24 silver.

Copper Pyrites, or Sulphide of Copper.—This is the most abundant ore of copper. Composition : copper 34·6, sulphur 34·9, and iron 30·5. It is of a brass yellow colour, and resembles both specks of gold and iron pyrites. It may be distinguished from the former metal by crumbling when an attempt is made to cut it, and from the latter by its yielding to the point of a knife and its not striking fire, as well as by its deeper yellow colour streaked by a greenish black. Under the blowpipe it fuses into a steel-grey globule, which is magnetic. If the ore is of a fine yellow colour and yields readily under the hammer, it is good ore ; but if it is hard and of a pale colour, it is poor, through containing more iron pyrites. Its usual hardness is 3·5 to 4, and its gravity 4·1 to 4·3. Its varieties are :

Cuban.—Composition : 22·96 copper, 42·51 iron, and 34·78 sulphur.

Variegated or Purple Copper, or Variegated Copper Pyrites. *Bornite.*—Composed of 55·6 copper, 16·4 iron, and 28 sulphur. Sometimes called 'horseflesh ore.' Colour, from red to brown ; tarnish from steel blue to pale grey, with a greyish black streak. Occurs in crystals near Redruth in Cornwall, and also in Connecticut.

GREY COPPER ORE (*Tetrahedrite*).—Composition : copper 38·6, sulphur 26·3, antimony 16·5, and arsenic 7·2. There are also slight varying quantities of iron, silver, and zinc. In a sample from Spain there was 10 per cent. of platinum, and in another from Tuscany 2·7 per cent. of mercury. Its colour varies from steel grey to iron black, sometimes showing a brownish hue—the less arsenic in the composition the darker the colour. Containing 17 to 31 of silver, the ore constitutes the silver fahlore of Freiberg. Its varieties are :

Antimonial Copper.—Containing 47 of antimony.

Bournonite.—20·3 sulphur, antimony 26·3, lead 40·8, and

copper 12·7. Of a brilliant metallic lustre, in colour from steel grey to iron black. Hardness, 2·5 to 3; gravity, 5·7 to 5·9.

Domeykite.—71·63 copper, 28·37 arsenic. A portion of each being often replaced by iron and sulphur. Tin or silver white with an iridescent tarnish.

Selenide of Copper.—64 of copper, with selenium. A silver white ore. Gives off a horse-radish-like odour under the blowpipe.

Tennantite.—A mixture of copper, iron, sulphur, and arsenic. Occurs in brilliant crystals in some of the Cornish mines near Redruth.

RED COPPER ORE (*Cuprite*).—An oxide of copper. Composition: 88·9 copper, and 11·1 oxygen. Hardness, 3·5 to 4; gravity, 5·7 to 6. Colour, cochineal to red, with a brownish red streak, and a bluish grey tarnish. Its varieties are:

Black Copper Ore (*Tenorite*).—60 to 70 per cent. of copper, with oxygen. Occurs in botryoidal concretions, dull black masses, and black powder associated with other copper ores; also in the lavas of Vesuvius. Originates in the decomposition of sulphides and other ores.

Chalcotrichite.—Composition like cuprite. Occurs in fine hairlike crystals of a crimson red colour.

Tile Ore.—An oxide of copper mixed with much peroxide of iron and other earthy substances. Reddish brown in colour.

SULPHATE OF COPPER (*Blue Vitriol*).—Composition: oxide of copper 31·8, sulphuric acid 32·1, water 36·1. Colour, sky-blue. Consists of sulphide of copper in solution. Contained in the water flowing from many copper mines, where the copper is usually, as at Parys Mountain and Rio Tinto Mines, derived from the solution by precipitation. Variety *Brochantite*, an insoluble sulphate of copper, containing 17·5 of sulphuric acid. Occurs in emerald green crystals at Ekaterinberg, in the Ural Mountains.

GREEN CARBONATE OF COPPER (*Malachite*).—Composition: 71·8 protoxide of copper, 20·0 carbonic acid, and 8·2 water. Hardness, 3·5 to 4; gravity, 3·6 to 4. Colour, light green with paler green streak.

Blue Carbonate of Copper (*Azurite*).—Composition: 69·1 protoxide of copper, 25·7 carbonic acid, and water 5·2. Hardness, 3·5 to 4·2; gravity, 3·7 to 3·8. Colour, azure blue with small blue streak; transparent to nearly opaque, and of a vitreous lustre.

The varieties of the two foregoing ores are:

Aurichalcite.—Composed of 29 copper protoxide, 44 of zinc oxide, 16·2 carbonic acid, and 9·9 of water.

Chalcophyllite.—Composition: 49·6 copper protoxide, 18 arsenic acid, and 32 water.

Chrysocolla or *Copper green* (silicious malachite).—A silica of copper, composed of 44·94 copper protoxide, 34·83 silica, and 20·23 water. Colour, azure blue to emerald green.

Emerald Copper.—50 protoxide of copper, 38·7 silica, and 11·3 water. Colour, usually emerald green, but occasionally dark green.

Erinite.—59·9 protoxide of copper, 34·7 arsenic, and 5·4 water. Colour, grass green.

Euchroite.—47·1 protoxide of copper, 34·2 arsenic acid, and 8·7 water.

Klinoclase (*Aphanese Abichite*).—62·6 protoxide of copper, 30·3 arsenic acid, and 7·1 water. Colour, bluish green to verdigris green.

Olioenite.—56·5 protoxide of copper, 39·5 arsenic acid, and 4 water, with a proportion of from 1 to 6 of phosphoric acid. Olive green to black green, with brown and olive green streaks.

Phosphorchalcite (*Lunnite*).—70·8 protoxide of copper, 21·2 phosphoric acid, and 8 water.

There are numerous variations of the last family, as *Atacamite*, *Ehlite*, *Libethenite*, *Tagilite*, *Volborthite*, and *Uranite*, all uniting phosphoric acid, and the minerals included in the carbonates of copper in slightly different proportions.

Cupriferous Cobalt Ores.—There are also some varieties of copper ores which shade off into cobalt on the one side, and nickel on the other, but they do not require special description here.

CHAPTER XV.

COPPER—continued.

The Ores of Copper in Russia—Ural Mountains—Western Side of the Ural Mountains—Caucasus—South Africa—The Cape—Algiers—Spain—Italy—Austria—Germany: Prussia—Norway—Sweden—France.

COPPER is mined in China, Japan, and India, but as yet we have but few particulars concerning the mode of its occurrence, so that in again commencing our westward journey we must content ourselves by starting from the eastern side of the Ural Mountains.

RUSSIA, *Ural Mountains.*—On the eastern side of this chain copper is worked in the Cambro-Silurian rocks, near Nijny Taglish. The strata consist of clayey shales, interstratified with calcareous beds, like our Llandeilo limestone. The ores are chiefly malachite, and the red oxides of copper, which occur in bunches and nests in the strata. The malachite occurs in large solid masses, one of which, a cube of 3½ feet diameter, is in the School of Mines at St. Petersburg. It was found at a depth of 280 feet, and weighed 580 tons.

The deposits near Bogolowsk are also found in similar limestones, which are interstratified with beds of trap. Between the limestones and the traps are clay deposits, in which the copper ores lie in bunches and nests, together with beautiful crystals of native copper.

Copper mines are also worked on the western side of the Urals, in permeated cupriferous beds, and irregularly stratified deposits in the Permian rocks. Southward, too, in the *Caucasus*, deposits of copper ore are worked that in 1876 yielded 536 tons of copper. We have no particulars of the nature of these

deposits, but probably they lie in the older rocks, like those on the east side of the Urals. The total production of copper in Russia last year may be estimated at 6,500 tons.

SOUTH AFRICA, *The Cape*.—For the present we must be content to pass the land of Midian above the head of the Gulf of Akaba—from whence Captain Burton has just returned with tons of mineral specimens, copper ore included—and take a run down to the far south-west of Africa, where copper mines are extensively and successfully worked in Namaqualand. The mines, of which there are two, are worked in deposits that are found in the range of mountains that, some 80 to 100 miles inland, run down the western side of South Africa. Here the basement rock is gneiss, overlaid with schists. Interbedded and intrusive felspathic rocks run in a general east and west direction at this point, and the cupriferous ores are distributed throughout portions of the felspar in grains and lumps, from a minute size up to several hundred pounds in weight. The felspathic rock is hence called the copper bearer. One of the principal mines is the Okatiep, near Springbok, 90 miles from the coast, and the other is Spectakel, in the Copperberg, 20 miles nearer Port Nolloth, with which port both mines are connected by a railway. The ore is chiefly purple and peacock ore, and some of the stopes are worth as much as four tons per cubic fathom. The average quality of the ore during the last three years has been 30 per cent. The prices obtained during the same period will illustrate the recent depreciation in the value of copper ore. In 1875 the price per unit was 16*s*., in 1876 14*s*. 7*d*., and in 1877 12*s*. 4*d*. The production has been equal to 12,000 tons a year, on which the profit last year was 83,579*l*.[1]

ALGIERS.—Retracing our steps northward, we find that copper ore is obtained in Algiers, near the foot of the Mouzia Pass, and the deposit is interesting as occurring near the summit of the chalk, which is here traversed by veins containing grey copper ore mixed with spathic iron. The total production of copper in Algiers in 1875 was rather over 3,000 tons. In

[1] *Mining Journal*, vol. xlviii. p. 605.

1878 we imported copper ore from Algiers to the extent of 3,674 tons.

SPAIN.—Crossing the Mediterranean into Spain we find numerous copper deposits, or, more strictly speaking, deposits of pyrites containing a percentage of copper. These occur as beds, and as fissures filled with metalliferous ores. Fig. 45, adapted from one given by Mr. S. R. Pattison, F.G.S.,[1] illustrates one of the former as it occurs in greenstone at the Buitron Mine, in the province of Huelva.

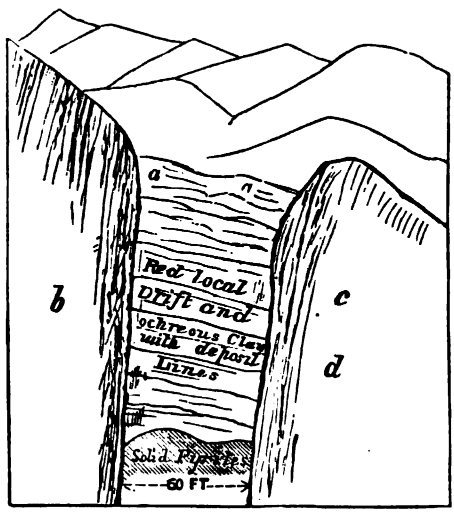


FIG. 45.—SECTION OF PYRITES DEPOSIT, HUELVA, SPAIN.
a a, Fahlband. *b*, Decomposed clay slate. *c* and *d*, Greenstone.

The deposit, *a a*, here is a nearly vertical bed about sixty feet wide. It is made up of fine bedded sand, permeated with an average of 3 per cent. of copper, 48 per cent. of sulphur, with about two shillings' worth of gold and silver to the ton of ore. For some distance from the surface the orey mass, *a a*,

[1] S. R. Pattison, 'The Pyrites Deposits of Huelva,' *Geological Magazine*, No. 2, 1872.

is decomposed. The whole deposit lies between greenstone, *b*, below, and clay slates, *d*, above.

The deposits of the Rio Tinto Mines, near Seville, are of a similar nature, the proportion last year being 2,735 tons of metallic copper to 211,000 tons of pyrites. The metallic copper was extracted from 520,391 tôns of ore. The water flowing from the mines yields 3½ tons of copper weekly by precipitation. The principal deposit is worked as a great open quarry, and it is estimated that there is still on the property some million tons of ore.[1] The total yearly production of copper in the shape of regulus and concentrated ores in Spain and Portugal combined, may be taken at 26,000 tons.

ITALY.—Bending eastward a little, Italy contains contact deposits of copper at Monte Catini, and which so far have retained their value in depth.

AUSTRIA.—North-east, in the Banat, whose geological structure has already been described, see figs. 17 and 36, copper ores are contained in the contact deposits that lie between the Cambro-Silurian rocks and the Jurassic limestones.[2] The ores are poor, seldom exceeding 3 per cent. They consist chiefly of copper pyrites, associated with arsenic, which are scattered throughout the gangue of the deposits, but are concentrated chiefly near the underlying syenitic rock. Mining for copper is not now carried on to any extent, the deposits being worked principally for the arsenic and sulphur they contain. At Tsiklova, the pyrites are largely mixed with argentiferous mispickel. Occasionally grey copper occurs mixed with blende, iron pyrites, and a small quantity of gold. The mines of Schmollnitz, in Upper Hungary, are of rather more importance. The annual production of copper in Austria is put down at 3,000 tons.

GERMANY, *Prussia.*—Passing northward by the Erzgebirge, where copper is to a small extent mixed with the other ores, to the Prussian province of the German Empire, the principal

[1] *Mining Journal*, 1877, p. 522; J. L. Thomas, *Mines of Rio Tinto*, 1865.

[2] *Mining Journal*, September 1877, *et seq.*

mining district for this metal is that of Mansfield. Here the ores lie near the junction of the Permian with the New Red Sandstone strata. The deposit is a cupriferous bed, from two to three feet in thickness, which stretches for miles across the country. It consists of a bituminous marly slate, throughout which fine particles of grey copper containing silver are plentifully disseminated. Copper pyrites also occur in regular veins in similar strata near Canisdorf in Lower Silesia.

In the north-west corner of *Nassau*, near Dillenburg, copper mines have been worked for many years. The strata apparently belong to the base of the Devonian group, and consist of an alternation of schaalstein—a variable kind of rock ranging from greenstone to slate, and black slates with eruptive rocks. The chief veins run NW. to SE. with branches running obliquely to their course. The larger lodes are from six to seven feet wide. They traverse the whole series of strata. They are unproductive in the black shale, are moderately productive in schaalstein containing an admixture of calcareous spar, more productive in the same rock when it is of a green colour through the prevalence of chlorite, and most productive when the schaalstein is impregnated with iron.

The whole German Empire produces about 3,000 tons of copper yearly.

NORWAY.[1]—Far to the north-west, in northern Norway, in lat. 70°, are the copper mines of Alten. The strata apparently belong to the Lower Cambrian group. They consist of dioritic and hornblendic rocks. The copper ore deposits are found in these rocks, and do not extend into the slaty rocks with which they are interstratified. Adjacent to these mines are those of the Rai pas Vara mountain, where a group of veins traverse a half-crystalline limestone in the same geological group. In the upper part of these veins gossan with the arseniates and carbonates of copper prevails, but in depth the ore is the variegated. The lodes cease to be productive when they pass into the slates. The production of copper in Norway and Sweden combined may be taken at about 3,000 tons.

[1] *Ann. des Mines* (5), iii.; Whitney's *Metallic Wealth.*

SWEDEN.—The copper deposits of Sweden occur in similar strata to those of Norway, and are found under the similar varying conditions. The important mines of Falun are worked in a great inverted cone of copper ore, as shown in fig. 46.

The containing rock, 1 1, is a grey quartzose mass, divided into little ovoid masses by curving belts of chlorite. The centre of the cone, 2, is made up of iron pyrites, around which, in 3 3, there is an encircling mass of copper ore, which

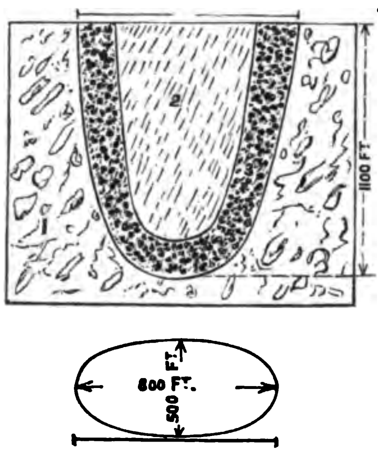


FIG. 46.—DIAGRAM SHOWING THE MODE OF OCCURRENCE OF COPPER ORE AT FAHLUN IN SWEDEN.

1 1, Grey quartzose mass. 2, Iron pyrites. 3, Copper ore.

averages, after sorting, from $3\frac{1}{2}$ to 4 per cent. of copper. At Areskuttan and Gustavsberg, the ore is found in 'fahlbands,' as copper pyrites spread throughout crystalline schists, the average yield of the ore being about 4 per cent. of metallic copper. In some of the Swedish copper ores silver to the extent of 20 to 30 ounces to the ton is found. In some recently discovered deposits in a white limestone in North Norway no less than 2,000 ounces of silver are found to the ton of copper ore.

FRANCE.[1]—In France blue and red carbonates, with black

[1] Cailloux, *Mines metalliques de la France.*

oxide and copper pyrites, were formerly obtained near Lyons. They occurred in irregular beds at the junction of the New Red Sandstone with underlying micaceous and talcose slates belonging to a much older group of rocks. The ores became pyritous as they passed into the slates. This district was famous for its beautiful crystals of *azurite* and *red oxide.* M. de Cailloux enumerates a great many districts where mines are worked for copper, but it is usually in conjunction with the ores of lead and silver combined, and there does not seem to be anything distinctive enough to require special attention. The returns of the production of copper for the year 1869 include pyrites, which together gave a total of 92,519 tons, the proportion of copper probably not exceeding 2,000 tons.

CHAPTER XVI.

COPPER—continued.

British Isles—Cornwall: Geological Structure and Characteristics of the Mining Districts of the county—Special Features of Lodes—Dolcoath Mine—History of Copper Mining in the West of England.

BRITISH ISLES.—We again cross to the British islands, which, for their size, are the greatest copper-producing countries of the world.[1] The total number of mines making returns of copper in the year 1877 was 101. These gave an aggregate of 79,252 tons of ore, of the value of 317,186*l.* 7*s.* 7*d.*, or an average of slightly over 4*l.* per ton. The ore gave 4,694 tons of metallic copper, of the value of 392,300*l.* This would show an average of about 17 per cent.; but there is included in the total of the ores nearly 1,000 tons of regulas, deducting which the percentage would be materially reduced.

Of the 101 mines, 65 were situated in Cornwall, which county contributed 43,016 tons of ore; the average price for the year being 4*l.* 17*s.* per ton, and the average production to the ton of ore 6⅝ per cent. The average standard price of metallic copper was 113*l.* 8*s.* per ton. At the present time the price is only about three-fifths of that amount. In 1879 the production of copper ore in the British Islands was 44,213 tons.

Cornwall.—From its situation on the south-west of Great Britain, from the number and importance of its copper mines, and from the scientific interest attaching to its mineral deposits, Cornwall deserves our first and special attention.[2] The county forms the south-western promontory of England, and it will help

[1] Hunt, *Mineral Statistics of Great Britain and Ireland*, 1877.

[2] Pryce, *Mineralogia Cornubiensis;* De la Bêche, *Report on the Geology of Cornwall and Devon;* Henwood, *Metalliferous Deposits;* *Cornwall Polytechnic Society Reports;* Moissenet, *Etudes riches parties Gisements de la Cornwall* (recently translated by Mr. Collins, F.G.S.).

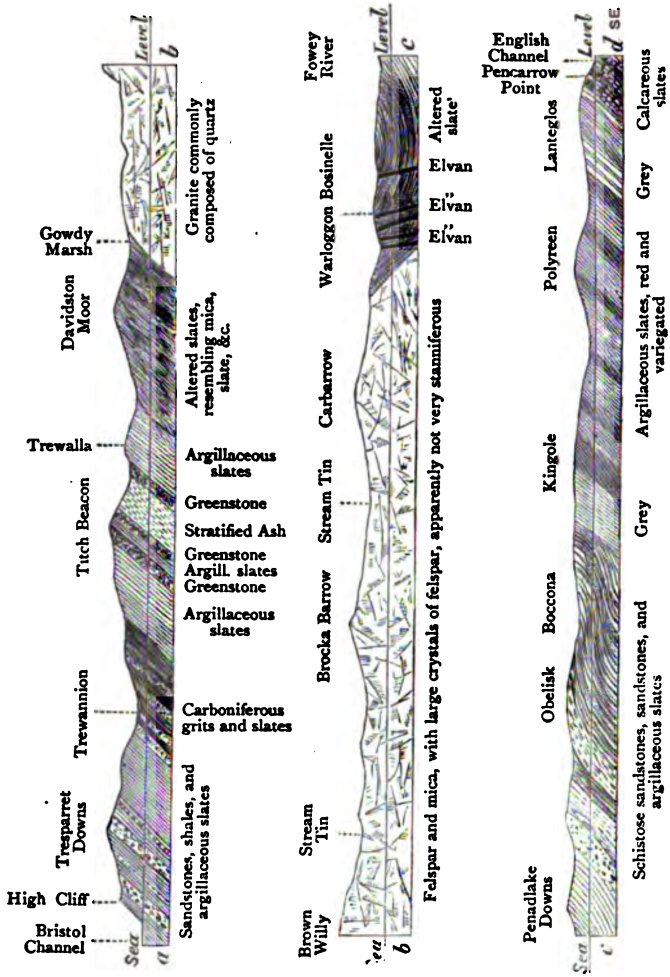


FIG 47.—SECTION FROM HIGH CLIFF, NEAR BOSCASTLE, TO PENCARROW POINT, NEAR FOWEY, CORNWALL.

us to understand both its copper and tin deposits if we now try to gain a clear idea of its geological structure.

Down its centre, or thereabouts, from Launceston to Land's End, there are four great bosses of granite. Passing north-east into Devon, the great granitic mass of Dartmoor makes a fifth; and if we extend the line south-west to the Scilly Isles, these form a sixth.

Following these granitic masses from the north-east to the south-west they occur in the following order: 1. Dartmoor; 2. Between Bodmin and St. Austell; 4. Between Truro, Redruth, and Marazion; 5. The promontory of Penzance and Land's End; and, 6. The Scilly Isles. The section, fig. 47, from the Bristol Channel to the English Channel, from north-west to south-east, across the second of the above granitic masses, will enable us to understand the geological structure of the country, and to fix the position, stratigraphically, of the different mines. It will be understood that parallel sections carried through the other masses would show the same general results.

Subject to local and minor variations, the structure of these granitic masses is very similar; it is a mixture of quartz, mica, and felspar, the felspar often prevailing, and when occurring in large crystals giving the rock a porphyritic character. Nests of schorl frequently occur which vary greatly in size, and the change from ordinary granite to schorlaceous, is observable by the gradual disappearance first of the mica and then of the felspar, leaving only a mixture of schorl and quartz.

Resting immediately upon the granite, and observable around the outlines of the masses where not covered by the newer rocks, is a series of thick-bedded micaceous and talcose slates, which become in places chloritic. Micaceous slate is the prevailing form of rock, and this becomes gneissic here and there by the addition of felspar. In their upper portion these slates become interstratified with, and are finally succeeded by hornblendic rocks, composed chiefly of lustrous hornblende and felspar, and which have not the slaty structure of the group below. These rocks underlie, and gradually pass upwards into serpentine rocks, as at the Lizard Point. The serpentine, however, as is the case with similar rocks elsewhere, sometimes protrudes through the

hornblendic rocks and then overflows them in roughly regular beds, the hornblendic rock being greatly changed at the point of contact. The change in structure from one rock to the other is usually very gradual.

Above these hornblendic rocks, with their eruptive and rudely-bedded metamorphic rocks, comes a thick series of grey argillaceous shaly slates, which are in places tinged with red. Where the series is most complete, these slates pass upwards into alternations of slaty with arenaceous and calcareous grits, varied by slates traversed by quartz veins.

The direction or strike of the beds follows the line of the upheaval of the granites, NE. to SW.; the dip being, of course, at right angles on both sides of the granitic masses. For the most part, the lower groups of slaty rock are highly metamorphosed, and it is difficult to assign them to their proper geological group. In maps they are all included as Devonian, which is, I think, with all deference to other observers, a mistake. My own interpretation of the ages of the strata I have just described is this: The micaceous and talcose slates belong to the Cambrian; the hornblendic slates with the serpentines and porphyries to the Cambro-Silurian; the argillaceous slates to the Silurian, passing gradually in their upper portion into the Devonian. In the last formation is comprised the bulk of the grits, slates, and sandstones that in South Devon overlap the older groups of rocks, and rest immediately upon the granitic mass of Dartmoor. The granitic masses, which are probably part of a vast sheet or mass that underlies the whole series, seem to have been protruded through the overlying strata towards the close of the carboniferous period. Compelled as I have felt myself to subdivide these Cornish strata which hitherto have been grouped as Devonian, and to assign to the lower parts of them ages older than the one that has hitherto been accepted, it has given me great satisfaction to find that Mr. J. H. Collins, F.G.S., of Truro, has in the course of his researches arrived independently at the same conclusion.

Besides the dykes 'elvans' of eruptive matter, mostly granitic, that traverse them, the whole of the strata described, granites included, appear to be traversed by two chief setts of

cracks or fissures. One sett, the oldest, ranges within 25 degrees either side of due east and west. The other, which we know to be the newest, because the cracks have cut and displaced those of the older, range 30 degrees on either side of a direct north and south line. The first sett of fissures are those which are most rich in metalliferous ores, especially those of tin and copper, and it has been observed that their direction coincides generally to that of the elvan dykes. The NE. and SW. lodes also correspond to the strike of the strata; but as the NW. and SE. lodes are equally rich, the wealth of the lode does not appear to have been affected by its coincidence with the strike of the beds.

Altogether five main epochs of intrusion, fracture, or disturbance may be defined in the strata of Cornwall: 1. Those formed in the granite either before or at the time of its protrusion through the slates. 2. That of the elvan dykes and courses that traverse both granites and slates. 3. That of the east and west tin and copper lodes. 4. That of the cracks and faults having a general north and south direction; and, 5. That of the east and west slides which may be of recent date. Each of these groups has its own system of minor fractures, diverging from it at all angles, like cracks from a central fracture on a window pane. Moissenet, in the work already named, endeavours to solve or determine the directions of these cracks by mathematical problems, but it is doubtful whether, from the extreme intricacy of the rules, the number of the exceptions, and the cumbersomeness of the process, his methods can ever be of practical use to ordinary miners.

The great mining districts of Cornwall and Devon are grouped around the granitic masses, the most productive mines being worked on the north or south flanks of these, along the centre of the line of upheaval extending from Penzance to Dartmoor, and where of course the oldest strata next to the granite are at or near the surface. The zone of productive mines extends seven or eight miles on each side this line of upheaval, making a belt about fifteen miles wide.

Generally speaking, the district around each granitic boss

has its own mineral characteristics. Beginning on the north-east, the western side of the Dartmoor mass is cupriferous. Dartmoor itself is stanniferous. Around the little boss of Callington the strata are both cupriferous and stanniferous, while north-east at Sidford, and south at Beer Alston, are the silver lead lodes. The mines around the granitic mass between Launceston and Bodmin are both copper and tin. There are also a few silver lead mines. On the SE. of the granite of St. Austell, the deposits are chiefly copper—the Fowey Consols Mine being here. Through the remainder of the circumference the mines are chiefly tin. The next district, that around the Redruth, Gwennap, and Penrhyn mass, is the great locality of the copper mines of Cornwall, although on the NW., near Gwinnear, tin is largely present, and silver ores have at times been profitably worked. The extreme western district, from Marazion to Land's End, produces tin, with a little copper worked at a few of the mines. Taking one of these granitic masses, with the strata described lying in their completeness around it, we find the centre (if the granite be favourable) and the innermost circle or lowest beds of micaceous and talcose slates to be stanniferous. Next, where the slate group passes into the hornblendic rocks, a circle of cupriferous mines; and third, where the clay slates rest upon the hornblendic and metamorphic rocks, an outer circle of plombiferous deposits. If, therefore, a well-defined lode could be followed downwards from the surface of this outer circle, we should find, first, in the clay slates deposits of lead ore containing silver; next, when we got down into the hornblendic rocks and portions of the micaceous slates, copper ores; and, finally, when we approached the contact of these last with the granite, and in the granite itself, the ores of tin. Scarcely any mine is deep enough to show the sequence of the whole three metalliferous deposits, but there are numerous examples of lodes containing copper ores in their upper portion and tin below, as I have described. Before we have finished our inquiries we shall see the accord of this arrangement with the universal stratigraphical arrangement of the various metallic ores.

The variations, therefore, in the character of the mines around these successive granitic masses, depend chiefly upon the age and nature of the strata thrown near the surface.

Bearing these considerations in mind, I proceed to observe that, although copper ores are found in all the mining districts described, the chief mining centres for copper in Cornwall and Devon are those near the town of Tavistock on the NE., and Redruth on the SW. Near the former town are the Devon Great Consols and the South Caradon Mines, and near the latter are the Carn Brea, Cremier and Abraham, Crofty, South Huel, East Pool, West Seton Huel, and West Tolgus, the great copper-producing mines of the two counties.

Copper ores prevail in the lodes that have a general east and west direction, and any deflection from the direction of a productive part of a lode influences its productiveness usually for the worse. The usual dip of the lodes is about 70 degrees from the horizon towards the north. They traverse both the granites and the overlying slates. Their average width in the slates is 7 feet, but they open out great widths, as, for example, 20 to 42 feet at the Devon Great Consols, and they contract to an average of 2 feet in the softer granite, and dwindle down to mere threads as they pass through hard felspathic, granitic, and porphyritic rock elvans, in passing through which they are often split up into a number of thin veins. This contraction of the lodes in hard rocks has occasionally led to the abandonment of mines. Thus Carn Brea Mine was abandoned fifty years ago, through the approximation of the walls of the lode to each other. Some more hopeful adventurers subsequently resumed work, and followed the thread of the lode until it expanded, and was found to contain a rich bunch of ore. The produce of this mine in 1876 was 1,174 tons.

The lodes are filled chiefly with the fragments and re-deposited grains of the rocks they traverse. A fresh combination of substances has, however, usually taken place, so that they are found in layers following the course and parallel to the walls of the lode. The silica frequently assumes a crystalline

form, the crystals coloured by fluorine pointing across the lode (as shown in figs. 48, 49, 50, adapted from De la Bêche), and the clay lying in layers between.

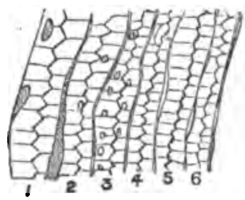


FIG. 48.—LODE NEAR REDRUTH.

1, Quartz and purple fluorspar. 2, Quartz, with copper pyrites. 3, Quartz, with yellow copper ore. 4, Quartz and purple fluorspar. 5, Quartz. 6, Quartz, with sprigs of yellow copper ore.

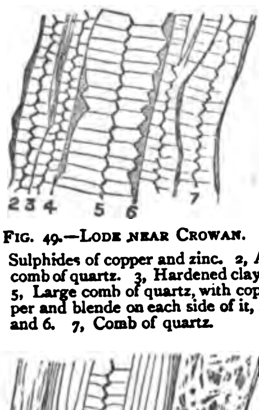


FIG. 49.—LODE NEAR CROWAN.

1, Sulphides of copper and zinc. 2, A comb of quartz. 3, Hardened clay. 5, Large comb of quartz, with copper and blende on each side of it, 4 and 6. 7, Comb of quartz.

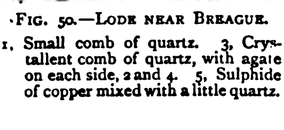


FIG. 50.—LODE NEAR BREAGUE.

1, Small comb of quartz. 3, Crystallent comb of quartz, with agate on each side, 2 and 4. 5, Sulphide of copper mixed with a little quartz.

Copper ores do occur in the basement granitic rock, and in the newer protruded granitic rocks, but they are most abundant in the slates not far from their point of contact with the metamorphic rocks and granites. In the slates also copper is more plentiful in some varieties than others. The favourite colour of the miners is blue, of a light colour and of a fairly compact structure, but not too hard. In the Gwennap district, for example, the lodes became poor as they passed into red slate. In the Old Godolphin Mine the lodes were rich in pale blue slate, but poor in black. At the Fowey Consols Mine the pitch or dip of the ore follows that of the blue beds of slate rock, and Pryce[1] says that 'of all the killas the cinerous or pale blue is the most desirable as the enclosing stratum of a copper lode.' Where the strata is thus favourable the lodes are productive of copper high up in the series, some of them yielding copper immediately under the fossiliferous beds.

Fig. 51 is a reduction of an old plan of the workings on a

[1] *Mineralogia Cornubiensis.*

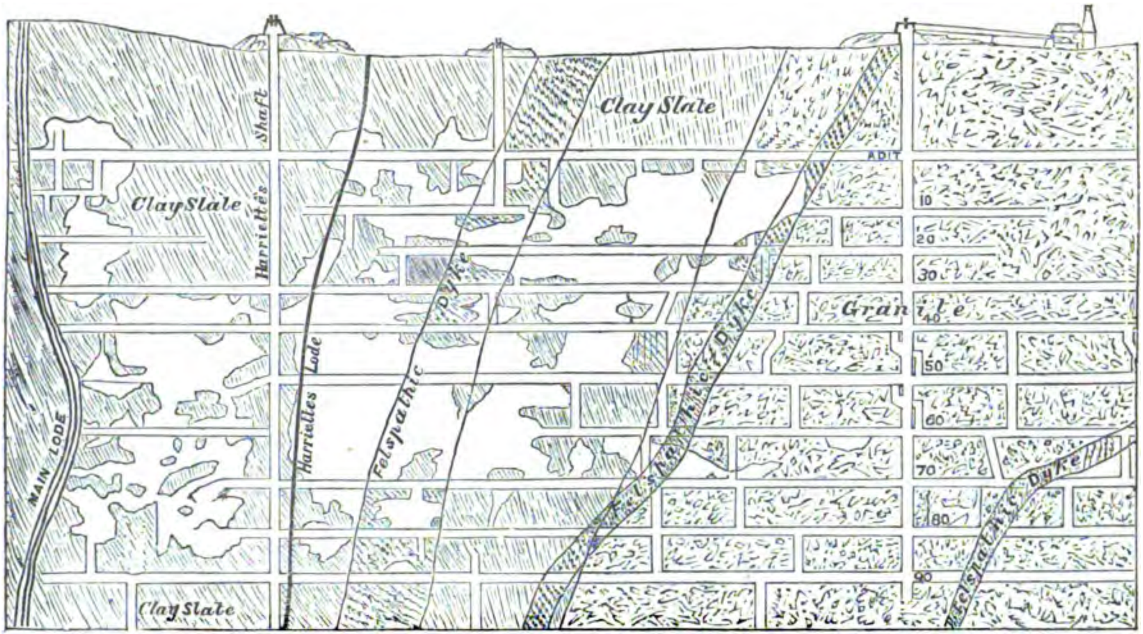


Fig. 51.—Old Section of the Workings on the Counter Lode, Dolcoath Mine. $1' = 20$ **Fathoms.**
The mine has since been carried much deeper.

contra lode at the Dolcoath Mine,[1] and is interesting as showing the proportion of productive ground in the slaty rock and in the granite, as shown by the amount of stoping done in the two rocks. The lodes are usually poor in the greenstones, or 'irestones,' as they are locally called, of Cornwall. It is in soft and easily decomposable granite that the lodes bear ore when they do at all in that rock. They are often productive when approaching an elvan course, and sometimes within it; but this depends upon its particular lithological character, and usually dykes of hard, compact, intractable rock are barren, and the lodes pinched. Ore is usually plentiful where two lodes meet at an acute angle, and poor on the obtuse or broad side of the meeting point.

The prevailing ore of copper in the region is the yellow, or bisulphide. Next to this comes the sulphide, or grey and black ore of the miners, and it is in this form that copper is found near the surface and by the cross courses. Usually the yellow ore holds out in depth. The more uncommon ores are the red oxide, the carbonates and silicates, and the arseniates. Phosphate of copper is rarely seen. The common metalliferous associates of the copper are the sulphides of iron and zinc, which occasionally occupy the whole of the lode. Arsenical pyrites are also found, especially in the Tavistock district, and throughout Cornwall they are considered the precursor of copper. Sulphide of lead occurs in small quantities. The figs. 48, 49, and 50 illustrate a frequent arrangement of the metallic ores in Cornish lodes. For some depth from the surface the lodes are made up chiefly of gossan or earthy brown iron ore, containing the black ore of copper—the sulphide having been largely replaced by oxygen. Lower down, beyond the reach of the atmospheric influences, the ore becomes a bisulphide, and it is this yellow ore that usually holds out in depth. In the granites and near the surface there are numerous 'vughs' or cavities, which are lined with crystals of quartz often

[1] Etymology: Welsh, *dol*, a meadow; *coch*, red: Red Meadow, from the soil being tinged red with the ores of iron and copper.

coated with native and ruby silver. In slate such cavities, when they occur, are mostly coated with iron and copper pyrites.

Copper mining in the West of England is of comparatively recent origin. Carew, writing about the year 1600, says that copper is found in sundry places, but he could not find that it was profitably worked. At one mine he knew that the ore was shipped to be smelted. For years after this time copper ores were neglected, roads being mended and walls built with them. About 1690–5, a Mr. Coster, of Bristol, with some other persons, went into Cornwall and bought copper ore for from 2*l.* 10*s.* to 4*l.* per ton. Competition arose, and contracts were made for the entire produce of mines at 5*l.* per ton. Some years subsequently, a gentleman from South Wales is heard of buying a lot of 1,400 tons of ore, that had been lying at a mine for a long time, at 6*l.* 5*s.* per ton, and another lot at Roskean for 7*l.* per ton.

From about the year 1726 we get regular returns of the quantities of ore and the prices realised. William Pryce, writing in 1778,[1] gives the following particulars, which are interesting for comparison with the present annual yield and price:

Dates	Total yield for the ten years	Average prices
Ten years.	Tons.	£ s. d.
1726 to 1735	64,800	7 15 10
1736 to 1745	75,520	7 8 6
1746 to 1755	98,790	7 8 0
1756 to 1765	169,690	7 6 6
1766 to 1775	264,273	6 14 6

The quantity of copper ore raised in the counties of Devon and Cornwall, in the year 1876, was 59,292 tons, or double the quantity raised a century ago. The average price per ton of ore for the five years ending 1876 was 4*l.* 11*s.* 4*d.* The average quality for the same period was 6¾ per cent. of metallic copper, or slightly over 13·6 per unit; the average standard for metallic copper for the same years being 101*l.* 5*s.* 2*d.* per ton.

[1] *Mineralogia Cornubiensis*

CHAPTER XVII.

COPPER—continued.

Cupreous Sandstones of Cheshire and Salop—The Limestones of Salop and North Wales—The Parys Mines of Anglesea—The Copper Turf of Merioneth—Copper in Carnarvonshire and Cardigan—North-West of England—County Wicklow in Ireland.

Cupreous Sandstones of Cheshire and Salop.[1]—Of a different age and character are the copper deposits in the Lower Keuper beds of the New Red Sandstone of Cheshire and Salop. At Alderley Edge, in Cheshire, a copper mine has been successfully worked for some years. Its production in 1875 was 8,336 tons, and in 1876, 7,328 tons. Through the recent low price of copper, however, the mine has had to be given up. While I write the plant is being sold and the mine abandoned. The deposit consisted of a portion of a sandstone bed impregnated with copper. The dip of the bed was very steep to the SW., the strike being, of course, at right angles to the dip. The ores were the blue and green carbonates, of a poor quality, from 2½ to 3 per cent. The ore was associated with earthy cobalt ore, and the bed partook largely, as may be supposed, of the character of the adjoining rocks.

Of a similar character was the deposit that was worked at Eardiston, near West Felton, Salop, about thirty years ago. This also consisted of a cupriferous bed, now showing well-defined boundaries, separating it from the adjacent sandstones, and then graduating into them, being really a mineralised zone of sandstone. At its outcrop, it contained a good deal of brown earthy iron ore. It varied in thickness from a few inches to five feet. It contained cavities lined with mammillary mala-

[1] See also Henwood's *Metalliferous Deposits.*

chite, and was richest in copper ore near its upper and lower boundaries, where it abutted on faults in the sandstones. It was subdivided into four layers, thus—

1. Red sandstone sprinkled with malachite and grey copper ore.

2. Sandstone with grains of malachite.

3. Ferruginous sandstone.

4. Ferruginous sandstone, largely mixed with malachite and with grey copper ore.

The ores yielded ·008 to ·025 of metal, and the aggregate production from 1841 to 1843 is given at 2,500 tons. The deposit was followed down its dip for sixteen fathoms, when a tough clay filling a line of fault cut it off.

Sandstones of the same age in the Peckforton Hills of Cheshire, that range between the two localities just given and those that overlie the Coal-measures of Cannock Chase, are in places similarly impregnated with copper.

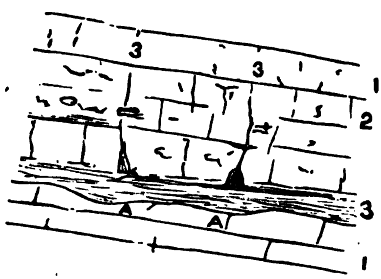


FIG. 52.—SECTION OF LIMESTONE STRATA AND CUPREOUS SHALE BED AT PANT, NEAR OSWESTRY, SALOP.

Limestones of Salop and North Wales.—The Carboniferous limestones that range from Shropshire to Anglesea have been worked at various times for ores of copper. Old mine works, attributed to the Romans, abound on Llanymynech Hill, which is partly in Shropshire, and attempts at mining with varying degrees of success have been made of late years in the same locality.

Fig. 52 illustrates the manner in which the deposits occur at this end of the range: 1 1 are the ordinary pale-coloured limestones of the lower division of the series; 2 is a considerable thickness of brownish yellow sandy limestone, full of small cavities lined with crystals of quartz and carbonate of lime, beautifully variegated with the sulphides, but chiefly with the

blue and green carbonates of copper; 3 is a thin shale bed, impregnated with the above ores to the extent of 2½ and occasionally 3 per cent.—the ores being richest and most abundant underneath the cracks, 3 3, that run up into the limestones, as at A A A.

At the NW. end of the range, on the mainland, is the Great Ormes Head. Mines were successfully worked in similar deposits to those just described until within the last twenty years. The same cavitous limestone, impregnated with copper, and the underlying cupriferous shale bed were present there. The accumulations of copper ore were found and worked along the course of a flat fault, known as the 'Hanging Mawr.' Crossing this fault from NW. to SE. was another sharper fault, called the Cyllell, or Knife, and near the point of the intersection of these two the largest deposit of ore was found. Both at Llanymynech and the Ormes Head the source of the copper appears to have been the overlying cupriferous limestone beds, from which the ore had been carried by the infiltration of water into places favourable for its deposition.

Limestone of Staffordshire and Derbyshire.—An important copper deposit was, at the close of the last century, worked at Ecton, near Hartington, on the borders of these two counties. It occurred as a succession of pockets connected by fissures, which were followed to a depth of 1,320 feet. The limestone was of a blackish brown colour, and the beds were much broken and confused. The ore was chiefly sulphide, and was often very rich, yielding, it is said, from 40 to 60 per cent. of copper. The ores were also noted for their great beauty of form and colour. The mine was a productive and profitable one, and it employed at one time about 1,000 work people. The ores were associated with carbonate of lime and barytes.

ANGLESEA.—*Parys Mines.*—From the Ormes Head we look across the eastern end of the Menai Straits to the northern corner of Anglesea. Here, in Parys Mountain, near the town of Amlwch, the most important copper mine of Wales has been worked for about a century and a quarter.[1] Previous to this

[1] Pennant, *Tour in North Wales.*

time there were traces of old mines, the remains of furnaces, and lumps of smelted copper with traces of lead ore lying about, which led Alexander Fraser, a mining adventurer from Scotland, to select the locality as the scene of his explorations. Shafts were sunk and ore discovered, but the operations were stopped by the influx of water.

A lease of the ground was, two years afterwards, included, much against the will of the lessors, Messrs. Roe & Co., in the lease of other mining ground in Carnarvonshire, by the owner of the two grants, Sir Nicholas Bayley. Ore was again reached, but worked for some time at a loss. The lessees gave their agent orders to stop the works, but he, as a final effort, divided his men into ten gangs, and put them to make trial holes near a spring strongly charged with copper. In two days better ore was struck at a depth of only seven feet from the surface. From then until now the mine has been successfully worked, the profits during the interval being estimated at not less than 7,000,000*l.* The production of ore in 1875 was 2,910 tons, and in 1876, 2,512 tons. At present, with the exception of the precipitation pits and the carrying on of some deeper explorations, the mine is, owing to the very low price of copper, lying idle. The mountain in which the mine is worked is supposed to take its name from Robert Parys, who was Chamberlain of North Wales in the reign of Henry IV. The adjacent mine to the east is called the Mona, and a recent discovery of ore under the old workings is likely to restore this mine to its old prosperity.

Figs. 53, 54, and 55, reduced to scale from the working plans of the Parys mine, will illustrate the position and nature of this important deposit of copper ore.

Fig. 53 is a section from south to north across the strata, which are tilted up at a high angle from 60 to 70. 1 is a thick series of clay slates, traversed by veins of quartz and felspar, and contains layers of the same, as well as of greenstone ; 2, a thick mass of rock that varies in composition along its course from slate to huge bodies of quartz, the whole mixed up with chlorite

and disintegrated felspar, with earthy brown iron ore, and con-

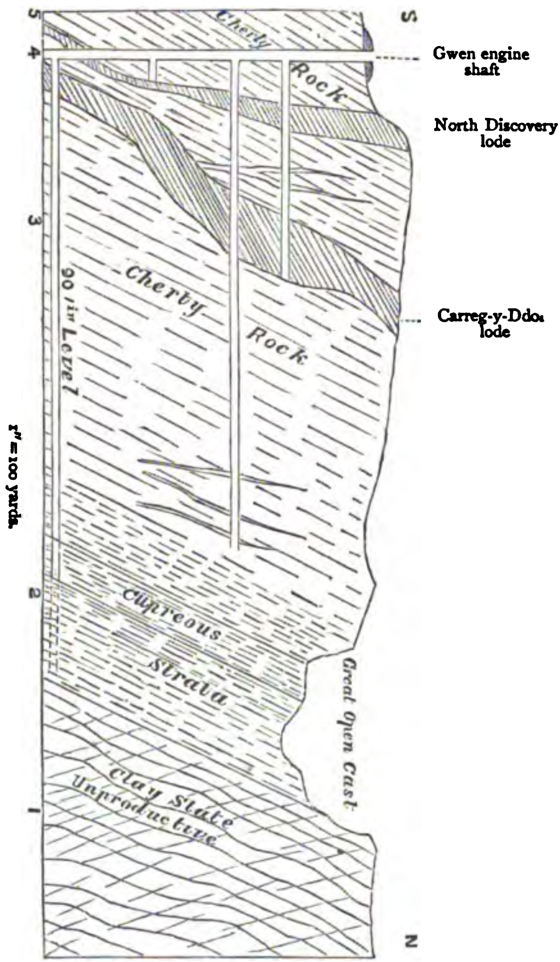


FIG. 53.—PARYS MINE; SECTION ACROSS STRATA AND DEPOSITS.

taining the great copper deposit; 3 is a thick belt of quartzose

rock, often cherty in character, that forms the crest of the mountain; 4, a series of beds similar to No. 2; and in 5 we have the series surmounted by a great thickness of clay slate. The whole series belong to the Cambrian group of strata, probably the upper part of the Lower Cambrian. The mineralised portions are Nos. 2 and 4. In two there has been a thick succession of mineralised beds, and in 4 only two such beds. The beds of No. 2 have been worked as an open quarry, of which a cross section is given in fig. 53, and a longitudinal section in fig. 54.

A reference to fig. 55, which represents the North Discovery lode, will illustrate the way in which the copper ores were distributed throughout the thick series of similar beds that have been quarried from the great open cast. The mineralisation of the beds is continued to the east, where, on the other side of the cross course, which is an upthrow to the east, they are worked in the Mona Mine. It will

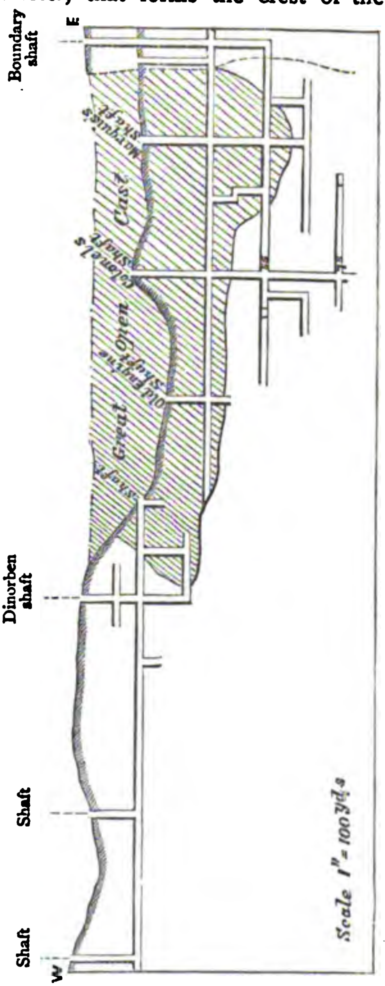


FIG. 54.—PARYS MINE; SECTION OF WORKINGS ON GREAT OPEN CAST LODES.

be observed that the mineralisation ceases on the west. It is, however, renewed in a short distance in another form, as will presently be explained. Whether the ores will continue in depth

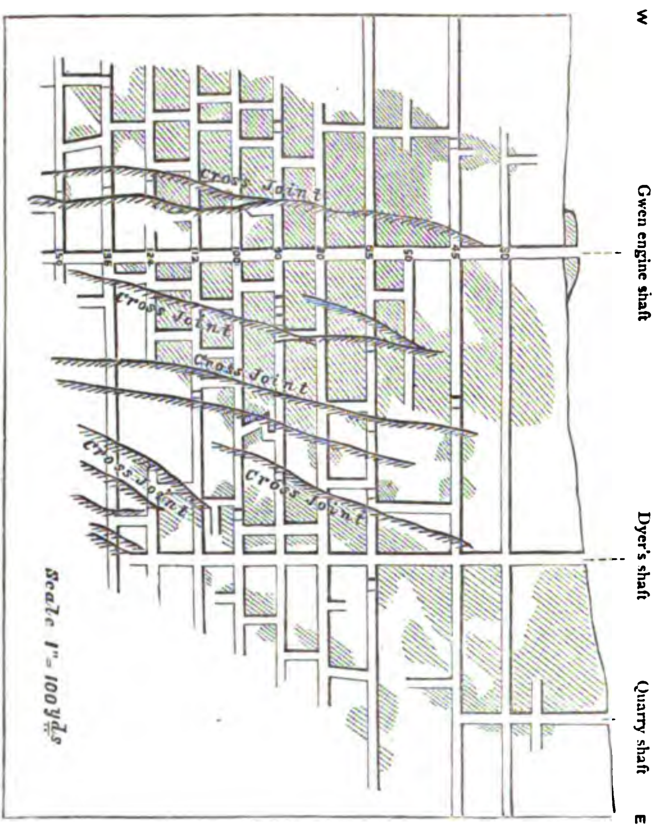


Fig. 55.—Parys Mine: Section of Workings on North Discovery Lode.

or die out in a wedge form will be proved as the lowest level is brought into the ground under the open shaft. At present there are slight indications of ore. In revising these pages for

a new edition. I am glad to add that now, April 1880, the yield of the lode in this lowest level is given as from 3½ to 4 tons of copper ore per fathom.

The copper ores are distributed throughout the mass, as shown in the section of the North Discovery lode. The ores consisted of nests of earthy black ore near the surface, passing into yellow pyrites in depth. Rarely there are small quantities of native copper, and throughout the mass there are numerous cavities lined with crystals of copper and sulphate of lead. The ores are classified for commercial purposes thus:

Halvans.—Containing 1½ per cent. of copper, and a good deal of sulphur.

Poor Ore.—3 to 3½ per cent. of copper, and much sulphur.

Ordinary Ore.—6 to 7 per cent. of copper, some sulphur.

Good Ore.—20 per cent. of copper.

Precipitate.—This is formed from the water pumped and flowing from the mines, and from the rain water that has percolated through the waste heaps. It is all arrested in a very complete system of long square pits. Waste iron and tin clippings are thrown in these, the sulphuric acid that is in the water seizes hold of them, the particles of copper suspended in the water fall to the bottom of the pit, and, mixing with the iron dissolved by the sulphuric acid, form a precipitate ranging in value from 15 to 30 per cent. of copper. The spent water also is caused to flow through a long series of tanks, in which the earthy brown iron ore is finally precipitated as ochre, for which it is sold, the water flowing off as pure as is practicable. The ochre is sold at prices ranging from 11*s.* to 21*s.* per ton.

About a mile to the west of the Parys Mine, at Morfa Ddu, where what seems a continuation of some of the beds worked in the great open cast are crossed by an east and west course, is a peculiarly mineralised deposit, locally known as bluestone. This bluestone requires special careful chemical operations to extract its contained metals. As proved by Messrs. Hills

& Son, of Amlwch, who have worked it, it is composed as follows:

Copper	2 per cent.
Lead	16 ,,
Zinc	32 ,,
Silver	7 ozs to the ton.

Sulphur, iron, antimony, and manganese in small proportion.

COPPER BOG OF MERIONETH.—The mention of the copper-charged water at these mines leads to a notice of the copper bog near Moel Hafod Owen, west of Rhobell Fawr, near Dolgelly.[1]

The turf filled a hollow in the hills, the strata of which are talcose schists, felspathic rocks, and greenstones of the Upper Cambrian group, which are dotted and intersected with nests and strings of copper pyrites.

The water passing over and through these copper impregnated rocks, flowed into the bog, the moss of which thus became charged with carbonate of copper. Ore to the value of many thousands of pounds was formerly extracted by burning the turf in kilns, and separating the copper from its ashes. The deposit is interesting as a recent example of the way in which some of the stratified mineral deposits we are considering became saturated with metallic matter.

A considerable attempt has been made, with much skill, and by the aid of excellent machinery, to work one of the copper pyrites lodes of the district at Glasdwr, near Dolgelly, but from the poorness of the ore, about 2½ per cent., although by careful dressing it was brought up to 6 per cent., the mine is at present idle. The matrix of this ore is a slaty bluestone, containing numerous ramifications of sulphide of copper and iron pyrites, with which is associated a small quantity of silver, less of gold, and some lead.

CARNARVONSHIRE AND CARDIGAN.—Lodes charged with sulphide and blue and green carbonate of copper traverse similar strata, and run up into the overlying Llandeilo beds in

[1] Ramsay, *Geology of North Wales.*

the country between Drwysycoed, where there is an ancient copper mine, and the region of Moel Hebog, Beddgelert, and Snowdon. Old mines, where considerable work has been done, dot the hillsides. The most important copper mine in Carnarvon at the present time is Tanybwlch. Its production of copper ore in 1878 was 595 tons, of the value of 5,500*l.*

The lodes are about four feet wide, and have usually been worked by adit levels. With the introduction of tramways into the district, some of these lodes in ordinary conditions of trade may yet perhaps be worked to profit. Copper is the prevailing metallic mineral of the region, and the lead lodes are charged with it. This is also true of a small portion of the lead district of the county of Cardigan, as at Esgair Ffraith and South Darren Mines, near Aberystwith. These two mines produced in 1878, 306 tons 15 cwt. of ore, that gave 31 tons 10 cwt. of pure copper.

NORTH-WEST OF ENGLAND.[1]—The last remark applies to this region. Copper pyrites are found in similar strata, and 1,007 tons were raised at the Coniston Mine, one of the oldest in the north-west of England, in the year 1876. The strata here are green slates and porphyritic rocks, which are traversed by six east and west ore-bearing veins, through which, a quarter of a mile apart, are two great north and south faults, which displace the east and west lodes.

The most productive of the latter is known as the Friddle. At the depth of 100 yards from the surface a large body of ore was struck, which has been followed downwards for 200 yards. A good deal of the richest ore has been obtained from a similar lode known as the Paddy End vein. The ore is chiefly copper pyrites, with occasionally some of the other forms of ore. Other mines of the district opened for copper have proved more productive of lead.

IRELAND: *Co. Wicklow.*—In 1876 Ireland produced 5,651 tons of copper ore, of the value of 29,213*l.* 8*s.* 6*d.*, or about

[1] Postlethwaite, *Mines and Mining in the Lake District.*

5*l.* 10*s.* per ton. In 1878 the production had fallen to 1,820 tons, of the value of 9,661*l.* 17*s.* 10*d.*

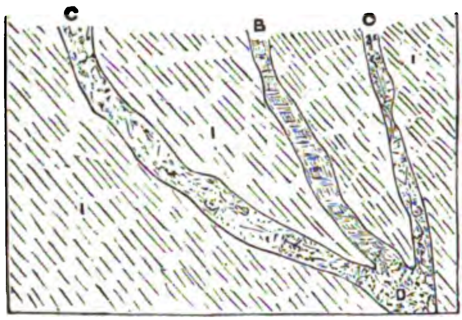


FIG. 55A.—MODE OF OCCURRENCE OF DEPOSITS OF COPPER AND IRON PYRITES AT OLD BALLYMURTAGH MINE.

1″ = 100 yards about.

1 1 Clay slate. C C, Copper pyrites. B, Iron pyrites. D, Great bunch of copper ore.

Although not now the largest producers of copper ore, the mines of Ovoca, in Wicklow,[1] are interesting as showing us great masses of strata permeated with copper and sulphur, like those just described in Anglesea.

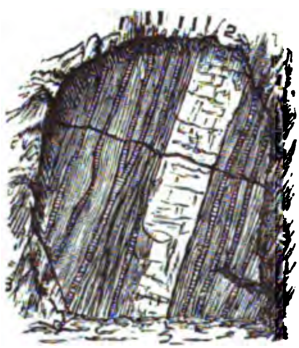


FIG. 56.—SECTION OF LODE AT TIGRONY MINES, OVOCA, WICKLOW.

1 1 1, Copper lodes. 2, Iron pyrites 14″ wide. 3 3, Beds of different coloured slates.

The basement rock of the country is a grey granite, which, where most productive of minerals, is mixed with green steatite, and occasionally there are large crystals of felspar that give the rock a hornblendic appearance. The granite is overlaid by a considerable thickness of micaceous slate, which in its turn is capped by a great thickness of clay slate, the series presenting a similarity to the succession of strata in

[1] Smyth, *Mines of Wicklow and Waterford.*

Cornwall. The copper has been most plentiful near the junction of the micaceous slates with the granite. The strata range from NE. to SW., and dip to the SE. at an angle of about 50 degrees. Fig. 55A shows a common mode of the occurrence of the ores, the deposit though not coinciding with, yet following roughly the dip and course of the bedding. It represents the nature of the copper and sulphur deposits at the Old Bally Murtagh Mine; and fig. 56, from Smyth, is a section of a similar deposit at the mines of Tigrony, on the banks of the Ovoca, showing strings of copper ore and a sulphur course running side by side and coinciding generally with the bedding. The whole width of the metalliferous beds here is about 40 yards, and the copper ores range in value from 4 to 8 per cent.

CHAPTER XVIII.

COPPER—continued.

Copper Deposits of North-Eastern America—Nova Scotia to Carolina—Mississippi Valley, Wisconsin—Lake Superior—Canada.

NORTH-EASTERN AMERICA.[1]—Deposits of copper have been found and worked to some extent in Newfoundland and in Nova Scotia,[2] the production of the latter province being, for 1877, 285 tons, an increase of 240 tons on the previous year.

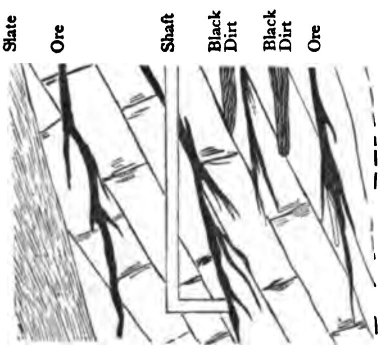


FIG. 57.—SECTION OF THE CUPRIFEROUS BED AT DOLLY HIDE MINE, MARYLAND.
L, Limestone, with copper veins, 100 ft. thick.

Mines are also in operation at various points along both sides of the Appalachian mountains, from Maine to the Carolinas. One of the most important of these is near the town of Manchester, in Connecticut, where a deposit of malachite has been worked at times since the middle of the last century. Other important mines of these Eastern States have been opened in Maryland, and fig. 57, adapted from Whitney, will show the character of the deposit at what was called the Dolly Hide Mine.

There is a band of crystalline limestone 100 feet thick,

[1] Whitney, *Metallic Wealth of the United States.*

[2] Gilpin, 'Recent Discoveries of Copper in Nova Scotia,' *Quarterly Journal Geological Society,* November 1877.

interstratified in places with slate, the whole of the beds being nearly perpendicular. In the limestone are numerous roughly parallel irregular beds or segregations of copper ore. This is mixed with quartz, coloured brown by iron and manganese. In depth, or along the course of the bed, argentiferous galena takes the place of copper, the galena yielding 45 to 50 ounces of silver to the ton of ore.

Besides deposits in the older Cambro-Silurian rocks and Carboniferous limestone, there are, along these Eastern States, copper deposits associated with the New Red Sandstone. These consist first of contact deposits lying between the Sandstone above and porphyritic rocks below, and secondly of cupriferous beds in the Sandstone itself, like those of Cheshire and Salop. In New Brunswick such deposits are associated with Coal-measure fossils.

Another important group of mines is successfully worked by the Union Consolidated Mining Company of Tennessee, near Ducktown, in the north-eastern corner of Tennessee, and on the western side of the Alleghanies. About 1,000 men are employed, and the producton is about 2,500 tons a year. The ore is black oxide, which was discovered in the year 1849. It yields on an average 25 per cent. of metallic copper. In depth it changes to yellow sulphide, with a yield of 6 per cent. of fine copper. The deposit varies in width from 15 to 60 feet, and is probably a mineralised bed of the same age and character—micaceous and hornblendic rocks—as those of Anglesea. Similar deposits occur in Alabama.

Dr. Sterry Hunt,[1] while admitting the general coincidence of these deposits with the strata, regards them, from their internal structure, as true fissure lodes. The massive chalcopyrite and other sulphuretted ores are traversed by larger crystals of hornblende and pyroxene, which are often broken across and the cracks filled with sulphides. There are, however, micaceous beds in the immediate vicinity of these lodes strongly impregnated with copper. So that there are both beds and lodes.

[1] *Engineering and Mining Journal of New York*, August 1877, p. 109.

Passing up the Mississippi Valley, a copper deposit is found at Mineral Point, Wisconsin. The ore occurs in a fissure in Cambro-Silurian limestone. The fissure is about 14 feet wide, and is filled with gossan to the depth of 15 feet. In the gossan are found lumps of the sulphide and carbonate of copper of all sizes up to 200 lbs. weight. Below that depth the fissure was filled with clay, with a little copper ore dispersed though it.

LAKE SUPERIOR COPPER REGION.—Pursuing our journey northward we reach the most important copper region of the North American continent, the southern shore of Lake Superior, about Kewenaw Point and Bay. There are traces of old shallow workings made by the Indians. The deposits of copper were also known to the Catholic priests who travelled in the region in the latter half of the sixteenth century. Mining operations by Europeans were commenced near the Forks of Ontonagon,

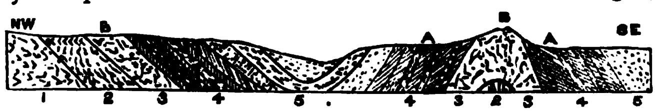


FIG. 58.—SECTION OF STRATA IN THE LAKE SUPERIOR COPPER REGION.

1, Granitic rocks. 2, Gneissic rocks. 3, Greenstone and hornblendic rocks, and conglomerates with interstratified slates. 4, Slaty rocks, with traps, &c. 5, Potsdam sandstone—Lingula flags. A A, Place of copper deposits. B B, Place of ironstone beds.

in the year 1771, by Alexander Henry, who does not seem to have been very successful. From this date the country was visited by military and scientific men, and by State officers, who were all surprised at the masses of native copper to be seen there, but who all concurred in the idea that the district was too remote for the ores to be profitably worked, especially considering the hostility of the Indian tribes.

In 1843 the country was ceded by the latter to the United States, and in the same and following years numerous miners, prospectors, and geologists, explored the region. Hundreds of permits or 'take-notes' were applied for; the most unlikely localities were taken. The excitement grew. Speculation and Stock Exchange tactics flourished, the whole followed by the usual result—a collapse. Some good mines however remained.

The diagram section, fig. 58, will illustrate the geological

structure of the country, and will show the position of the copper deposits, as well as those of iron, which we shall have presently to consider.

The lowest granite, 1, passes upwards into gneiss ; 2, 3 are hornblendic rocks and greenstones, covered by slates, calcareous in places, and interstratified by felspathic and hornblendic rocks ; 5 is a great thickness of what by its fossils is proved to be the Potsdam sandstone, the equivalent of our Lingula flags ; 3 B is an upward curve of the lower portion of the rocks 3 and 4 A 4 A are continuations, in a somewhat altered form, of portions of group 4. They here consist of conglomerates, traps, greenstones, and slates, resting on a central ridge or upward curved mass of choritic and gneissic rock, and contain the copper deposit. These consist of both mineralised beds and proper lodes.

The whole region has been grouped into four districts thus :

1. Kewenaw Point.
2. Isle Royal.
3. Ontonagon.
4. Portage Lake.

The section of Waterbury Mine (fig. 59) will show the detailed order of the strata in the Kewenaw Point district, and one of the bedded deposits. The upper greenstone, 1, is a compact crystalline trappean rock like dolerite. It has a thickness of 500 to 600 feet ; under it lies a bed of ash, often chloritic. Between this and the conglomerate 4, there is the ore deposit 3, containing thin sheets and particles of copper.

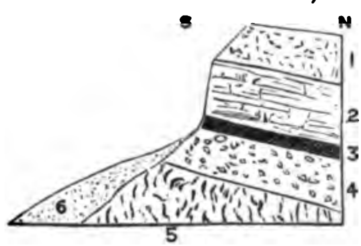


FIG. 59.—SECTION AT WATERBURY MINE, LAKE SUPERIOR.

1, Greenstone. 2, Chloritic ash. 3, Copper deposit, with thin streaks and specks of copper. 4, Conglomerate. 5, Amygdaloid at base of copper-bearing rock. 6, Drift.

Upper Cambrian rocks.

The conglomerate 4 thins out westward, as may be seen from the details given of the Eureka Mine, fig. 60.

The details of the beds between the crystalline greenstone, 1, and the amygdaloidal greenstone, 4, vary in their passage westward

from this point, as the section at the Lake Eureka Mine, fig. 60, will show.

The amygdaloidal beds, 5 of fig. 59 and 8 of fig. 60, alternate with sandstones and shales, and form a group of strata 4,000 to 5,000 feet thick, and constitute the great copper-bearing zone of rocks.

They are traversed at right angles to their strike by nearly perpendicular lodes, which have a usual width of three feet, but which open out to ten feet wide or more. There are no cross courses, but as the lodes pass from one kind of rock to another, they are often bent from a straight course. They

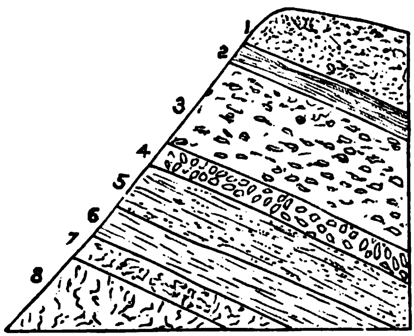


FIG. 60.—SECTION SHOWING DETAILS OF BEDS BETWEEN THE GREENSTONE AND AMYGDALOID AT EUREKA MINE, LAKE SUPERIOR.

1, Greenstone, 500 feet thick. 2, Veins of quartz. 3, Reddish conglomerate. 4, Greenish conglomerate. 5, Hard clayey matter, with specks of copper. 6, Hard clayey matter. 7, Trappean ash. 8, Amygdaloid.

traverse the whole series of strata from the underlying gneiss and greenstone, 3 B, to the Potsdam sandstone, 5, of the section fig. 58. The gangues of the veins vary in the different rocks. In conglomerate the earthy minerals are chiefly calcareous, in which the copper is concentrated into large masses. In the fine crystalline amygdaloids, which are the most productive ore-bearing rocks, the lodes contain quartzose matters, mixed with variable quantities of calcareous spar and zeolitic minerals. Copper is most abundant when the lode-stuff is a crystalline and drusy quartz, intermixed with granular car-

bonate of lime and prehnite. With the earthy minerals in most of the veins there are cemented brecciated fragments of the adjoining rock.

The veins seem lost when they pass up into the overlying Potsdam sandstone, and are not usually productive in the crystallising greenstone at the top of the sections, figs. 59 and 60, although they are close up to it.

The copper is found native, in particles and masses of all sizes, from those of microscopic minuteness up to 200 tons in weight. At the Cliff Mine, of which a section, adapted from

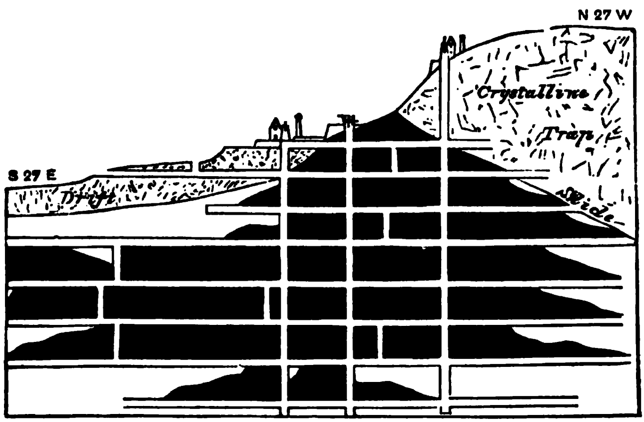


FIG. 61.—SECTION OF THE CLIFF MINE.
Dark parts show ground stoped.

Whitney, is given in fig. 61, sheet copper often occupies the entire vein. No part of the vein is so poor as not to be worth taking down, the average production of copper per fathom being 761 pounds.

The lode was first discovered at this mine in the crystalline trap or greenstone at the top of the bluff.

Its course down the escarpment was marked by a depression in the greenstone. In this rock the lode was only a few inches wide, and contained native copper and specks of silver beautifully incrustated with red oxide.

Half way down the cliff the lode expanded, and believing that it would increase in width downwards, Mr. Whitney recommended the opening of the lode at as low a point as possible. The débris at the base of the cliff was cleared away, and the vein traced into the amygdaloid below. A level was driven, and at a distance of 70 feet the first mass of copper was struck, and the productive character of the lodes in the strata below the crystalline trap or greenstone proved. The direction of the lode is N. 27° W., and it underlies 10 degrees to the east. Its average width is 15 to 18 inches, but it widens out in places to 3 or 4 feet. Its metallic minerals are exclusively native copper and native silver.

The silver occurs in spots and patches, as if it were soldered in the copper. It is most abundant in the lodes at the points of contact between two dissimilar beds of rock.

The copper is divided: 1st, into masses, often weighing many tons; 2nd, into barrel work, consisting of lumps weighing several pounds; and, 3rd, into stamp work, consisting of grains of copper. When a large sheet of copper occurs in the vein, the rock is removed on one side of it, a small tunnel is driven on the other side, which is charged with powder up to 12 cwt., and the lode blown down. In this way great masses of copper, weighing 60 or 70 tons, are blown down. These are of a tabular shape. They are broken or cut by chisel and hammer in the mine into sizes convenient for removal, and further broken on the surface so as to be suitable for shipment. The mines of the Isle Royal are very similar to those just described.

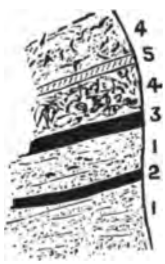


FIG. 62.—SECTION OF BEDS IN THE PORCUPINE MOUNTAINS, ONTONAGON COPPER DISTRICT, LAKE SUPERIOR, SHOWING BEDDED ORE DEPOSITS.
1 1, Sandstone. 2, Cupriferous deposit. 3, Contact cupriferous deposit. 4 4, Trap. 5, Bed of calc spar.

In Ontonagon the metal seems more widely dispersed throughout the rock. It occurs in beds between the traps and sandstones, and in seams and layers parallel with the bedding of the rocks, as shown in fig. 62. Also in true veins, whose direction coincides with that of the strata, but which dip at a different angle. In

one of these lodes at the Minnesota Mine, a mass of copper, weighing six tons, had been lifted from its bed and hammered all over by the Indians.

In the Portage Lake district there are not many regular veins, but the native metal is distributed in small masses, lumps, and grains, through regular metalliferous beds which differ little in other respects from the adjacent rocks. The most productive mine of this region at the present time is the Calumet and Hecla, which produces 900 tons of ingot copper monthly, or 10,800 tons a year. Besides this mine there is the Quincey, with a yearly production of 1,800 tons, of 80 per cent. value. The Osceola producing the same amount. The Central Mine, which produces the greatest quantity, and largest masses of native copper in the district. Its production of ingot copper is 1,200 tons a year. The Cliff Mine, which I have described, and some of the other old mines have fallen off in value, but it is hoped that explorations now in progress will revive them. The total present yearly production of the region may be taken at 15,000 tons.

CANADA.—In Canada, on the north shore of Lake Superior, copper mines have been worked with varying success in similar deposits to those just described on the south shore, except that the amygdaloidal trap (5 of fig. 59, and 8 of fig. 60) has given place to a compact quartzose sandstone, which passes into a jasper conglomerate. A lode worked near Prince's Bay, having a course N. 32° W., was mainly composed of talc, heavy spar, and quartz. It was about 12 feet wide, and contained yellow sulphide and variegated ores. So far the mines on the north of the lake have not been as successfully worked as could have been desired.

CHAPTER XIX.

COPPER—continued.

Western North America—Colorado, Montana, Nevada, and Arizona—Wyoming—Cuba—Jamaica—South America—Venezuela and Chili—Australasia—North and South Australia—York Peninsula—Flinders Range—Victoria—New South Wales—Japan—Inferences, and Concluding Remarks.

WESTERN NORTH AMERICA.—Copper deposits exist in Western Colorado, Montana, and in Arizona.[1] The remoteness of the localities from railway communication, and the eager concentration of mining enterprise upon gold and silver ores, has hitherto prevented most of these deposits from being worked. During the last two or three years, however, the copper mines of Clifton and Santa Rita, in Arizona, have been rising into importance. These deposits occur as contact beds in the strata of the Yankee and Arizona range of hills, which, resting on a base of granite, consist of quartzite, slaty and hornblendic rocks, with intercalated limestone, the whole being highly inclined. The deposits occur between the quartzose hornblendic rocks and the limestone. They are from ten to fifty feet thick, and consist of nearly pure red oxide of copper, which carries from 10 to 50 ounces of silver. Small bunches of copper pyrites and copper glance have been found in depth. At the Longfellow Mine the deposit has been worked to a depth of 230 feet, and at the Gleason to 90 feet, without any diminution in the quantity and quality of the ores.

In Montana the Buttes vein, discovered three years ago, is an important deposit: 1,000 tons of ore 35 per cent., and con-

[1] *Engineering and Mining Journal of New York*, January 1878, p. 53.

taining 15 ounces of silver to the ton, were raised from it in 1877. The lode occurs in strata of apparently the same age as those of Arizona, and the lodes are productive in hornblendic and quartzoze slates above granite. The ores are oxides near the surface, with copper glance below, with small quantities of carbonates.

In the Ewing district, south of Wyoming, and on the line from Colorado to Utah, deposits, consisting chiefly of oxides of copper, occur in contact deposits from 3 to 50 feet thick. There appear to be three principal courses of ore, inclining with the strata at a high angle, and traceable along the surface for thousands of feet. Near the surface the ore occurs in sheets of from 2 to 8 inches wide, very free from earthy matter. Samples assayed have shown silver as much as 50 ounces to the ton. The deposits lie between beds of slate and limestone.

Farther north, in the Upper Snake River Valley, are the Peacock and Monument Mines, where the deposits of copper are reported to be the most extensive on the Continent. There is no doubt that similar deposits will be found, at the same stratigraphical horizons, all the way from the extreme north, southwards through the States named, and those lying to the south. The total yield of copper from the mines west of the Missouri river for the year 1877 amounted in value to about 200,000*l.*, or say 15,000 tons.

CUBA.—As we pass southward we may notice briefly that copper mines were formerly extensively worked in this island. The deposits consisted of beds and masses that lay in the midst of greenstone and serpentine rocks, with their interstratified slates. The ores were the yellow sulphides mixed with iron ores. Near the surface the copper ores were oxidised, and in this portion of the deposits masses of native copper were found. The production of copper in Cuba was, in 1853, 2,200 tons. Similar deposits have been found in JAMAICA, where there are also lodes in which mines have been opened.

SOUTH AMERICA.

VENEZUELA.—Gaining the southern continent we find the mineral resources of this Republic rising into importance. One mine, the New Quebrada, shipped in 1877 4,446 tons of copper ore, of the percentage of 11⅝, and for the first four months of 1878 2,400 tons of 15 per cent. In PERU copper is largely mixed with silver, and both metals occur in veins, and also in beds and segregated deposits. Near Colcamba a segregated mass occurs in a variety of granitic rock.

CHILI.—This Republic is the representative copper-producing country of South America, and one of the largest copper-yielding countries of the world. Its yearly production of fine copper, for the ten years ending 1866, was 39,433 tons,

FIG. 63.—SECTION OF COPPER DEPOSITS NEAR COPIAPO, CHILI.
a, Veta; *b*, Guia; *c*, Manto:—copper deposits. *d d*, Quartzose and hornblendic rocks and slates.

and for the ten years ending 1876, 43,055 tons. The quantity raised in 1876 was 50,740 tons.

The deposits lie in the mountain range of the Andes, from opposite Copiapo to Valparaiso.[1] The strata in which they occur are foliated quartz and hornblendic rocks with felspar; occasionally there is calcareous spar, when the rocks become softer. There are both lodes and irregularly stratified deposits, and both often run roughly along the dip of the beds, which is from 30° to 55° W. The lodes ramify into the adjacent strata, as shown in fig. 63, which represents a deposit near

[1] See Henwood's *Metalliferous Deposits.*

Copiapo. The names of the different deposits are those by which they are locally known.

The lodes are charged with quartz, hornblende, felspar, and carbonate of lime. When they are very wide they contain great masses of quartz. In the upper portion these substances are mixed with iron ore. A lode at Punitaque was worked successfully for iron to a depth of 100 yards, and then its metallic contents changed suddenly to copper. Lumps of native copper occur in the midst of the earthy brown ore at the top, which are coated with red oxide, and earthy black carbonate, with which a little gold is associated. The ores change to sulphide in depth. The lodes widen out to 12 or 15 feet, but are often richest when not so wide. They are usually poorest when the rock becomes calcareous. The average quality of the ores from 1848 to 1853 was 18 per cent. of copper. Until of late years ores under 10 per cent. did not pay to work, but through improved machinery and appliances, ores of 5 per cent. and upwards are now profitably worked. Similar strata in the eastern half of South America are cupriferous; the production of Brazil for 1875 being estimated at 800 tons, and that of Buenos Ayres at the same quantity, of copper. In the latter country half the population are said to be engaged in mining.

We cross the Pacific Ocean, and notice lastly the copper deposits of Australasia.

AUSTRALASIA.—The production of copper on this continent for 1876 stood as follows:

Australia, North and South.—3,276 tons, of the value of 249,978*l.*, or over 75*l.* per ton.

New South Wales.—5,225 tons of ore, of the value of 58,271*l.*

Victoria.—37 tons.

The production of Australia was only half in 1876 what it was in the previous year.

Deposits of copper are found at various places, and the number will doubtless increase in the mountainous ranges, from Cape York on the north to the Australian Alps in Victoria on the south. The chief deposits hitherto worked are in the

Flinders range of hills, that run northward from near Melbourne, northwards in South Australia ; the two great copper-producing regions being those of York Peninsula and the Flinders Range.

The strata of the latter hills are the same as those of the general section of Victoria, the central ridge being the granite.

The copper ores occur in the overlying schistose, hornblendic, and quartzoze rocks. They are found together with gold in places along the range for some hundreds of miles. The principal mines are the Blinman, Nuccaleena, Yudanamutana, and Sliding Rock. The ore seems to occur in irregular beds and lenticular-shaped masses that lie in the hollow of the rocks near the surface, the covering, if there ever were any, having been swept away. There are also irregular ramifications of veins. The Burra Burra Mine, situated about 100 miles due N. of Adelaide, has been of such commercial importance that it will form a good example of the ways in which copper ores occur.

Overlying the ancient slaty rocks, but unconformable to them, is a tufaceous limestone that fills up the depressions on the surface and runs down into the cracks and crevices of the underlying rocks. On some hills this tufa is two or three feet thick—in other places so thin as merely to give to the slaty rocks the appearance of having been used in buildings, and having thus acquired a coating of mortar. In fact, this limestone very much resembles old mortar, both in consistence and appearance. When accumulated to any thickness, large fragments of the underlying rocks are imbedded in the limestone. Organic remains have not been observed in the limestone of this district, but this does not prove that there are none, and a further examination of it may reveal some.

In a depression on the eastern slope of a hill so covered with limestone the Burra Burra Mine is situated. This depression is somewhat triangular in shape—the base of the triangle near to, and parallel to, the ridge of the hill; the other sides much shorter, curved, and terminating below in a rocky creek, by which the waters of the mine are conveyed to the main creek. This depression is about half a mile long, and

300 yards wide in its broadest part, and is entirely covered with shafts and machinery for the raising of the ore, and crushing it, and two powerful steam engines for pumping the water from the workings.

In the deeper levels regular lodes are met with, running north and south, and containing very rich ore of malachite, red oxide, and grey sulphuret of copper; but above the 30 fathom level there is no appearance of lodes, the ores (malachite and blue carbonate) being deposited with the greatest irregularity in the soil, the limestone, and the harder rocks. These last mentioned ores are of great beauty. The blue carbonate often occurs in round nodules, with crystals of the greatest regularity projecting from the surface. There can, I think, be no doubt but that the malachite is an aqueous deposit. It is found in the form of stalactite, of slabs incrusting fissures, and of irregular-shaped hollow masses which have been deposited in cavities of the rock.

The Blinman Mine may be taken as another example. There is a mass of calcareous sandstone, which in depth becomes silicious. This sandstone is interspersed throughout with specks, patches, and strings of copper. It is also traversed by numerous veins containing copper ore, which coalesce, diverge, and form floors of ore 6 to 3 inches in width. The ore in the silicious sandstone consists of chrysocolla, malachite, and red oxide; but when, at a depth of about 250 feet, the sandstone becomes more silicious, the ore changes to a high quality copper pyrites. The ore is mixed with much iron. Its quality varies from 10 to 50 per cent., and it contains lumps of native copper assaying as much as 80 per cent.

An important lode or deposit of copper is found in dioritic rocks on the Thomson river, about five miles south of Stringer's Creek. This deposit is described as 30 feet wide, and consists chiefly of pyrites, with some carbonates and sulphurets. These lie in ferruginous quartz. Its direction is N. 15° W., and its underlie is only 20° from the horizon, and it is possible that it is after all a mineralised bed, or series of beds, like others we have noticed.

In New South Wales the ore raised is chiefly a sulphide, which occurs in lodes, the surface portion of which are filled with gossan. A lode worked at the Snowball Mine, between Gundagar and Adelong, is 8 feet thick, and is traceable on the surface by the gossan for 1,000 feet. The ore stuff of this lode consists of various qualities of poor yellow oxide, assays giving $7\frac{1}{2}$ per cent., yellow oxide with little steel grains $19\frac{1}{2}$ per cent., black-coated yellow oxide $22\frac{3}{4}$ per cent., and blue and green carbonates $22\frac{5}{8}$ per cent.

JAPAN.[1]—We may complete this journey round the world by observing that there are numerous copper-bearing lodes in Japan. The production is estimated at 3,000 tons yearly, and the number of mines is over 200. The most important mines are worked in the northern part of Nippon, in the province of Rikuchu, and in the island of Shikoku. The common ore is copper pyrites, but the variegated and grey copper ores are also found, native copper and the black oxide being rarely met with. The ores occur associated with iron pyrites and galena in quartz clay and fragments of the adjoining rock, that altogether fill nearly perpendicular lodes that traverse fine-grained porphyritic greenstone and altered slate rocks. The lodes vary from a few inches to three feet wide, one foot being the average. They have a general east and west direction, and are most productive in the porphyritic greenstone, having a tendency to thin out in the slaty rock. Lead is most abundant in the lodes running due east and west.

In the province of Iyo, at the Besohi Mine, there is a stratified deposit, consisting of massive copper and iron pyrites, with small quantities of quartz; this mineralised bed is from 1 to 10 feet thick, and occurs in the midst of clay slate, mica, schist, gneissic and quartzose rocks, which range NW. and SE., dipping at 50° to NE. The bed has been worked a length of about 2,400 feet, and to a depth of 1,400 feet. A similar deposit is worked at the Tanokuchi Mine, in the province of Tosa, at the junction of clay slate and diorite.

[1] Godfrey, 'Geology of Japan,' *Quarterly Journal Geological Society*, August 1878.

Reviewing the foregoing description of the copper deposits of the world, it will be seen that, with trifling exceptions, they lie in three well-defined stratigraphical zones. First, near the summit of the Lower Cambrian strata, just underneath the Lingula flags; secondly, near the base of the Carboniferous limestone; and, thirdly, in the sandstones of the Upper Permian and lower half of the Triassic strata; the exceptions being the deposits of the Banat, of whose precise age we are doubtful, not knowing whether they belong most to the older eruptive rocks or to the newer Jurassic strata, and also the deposits of the Mouzia Pass in Algiers, concerning which we need more specific information. The largest and most successful copper mines in the world are worked in the deposits on the first or lowest zone.

It will also have been observed how universally loose-grained dioritic, hornblendic, and felspathic rocks, with masses of loose drusy quartz, are associated with productive copper beds, and how seldom the mineral is found in workable form in simple clay slate, or in massive compact quartzites or greenstone. In Norway and Sweden important lodes traverse gneissic rocks of average texture, the coarse and fine compact varieties of the rock being unproductive of copper ores. Further, it will be seen how the mineral, which was originally spread throughout a bed or series of beds, is gathered in a concentrated form in the cracks by which the strata have subsequently intersected; and, finally, it will have been noticed how, when such cracks run up into the overlying Arenig and Llandeilo beds, copper ores become more scarce as they ascend, as in the lodes of Carnarvonshire.

CHAPTER XX.

TIN.

General Description—Modes of Occurrence—Alluvial Mining in Banca—In the Malay Peninsula—Tin Ore Deposits of Bohemia and Saxony—France and Sweden.

It is difficult to overestimate the value of this metal in the ordinary uses of life. To Britons it has especial interest from its ancient historical associations, carrying us back as it does in thought to the time between four and five hundred years before the Christian era, when traders from the East visited the ancient Cornubia, as Cornwall, from its horn shape, was called, to purchase tin of the natives. The metal is white in colour, malleable, but less so than copper, and is capable of receiving a high polish.

It is an unsettled point whether tin occurs in nature in a native form. It is reported as being found native as grains in the gold washings of the Ural, but some authors question the fact. Its ores are:

Cassiterite (*Tin Ore, Oxide of Tin*).—Hardness = 6 to 7; gravity, 6·8 to 7; chemical composition: tin, 78·38, oxygen, 21·62, but one or other of these elements is sometimes displaced by iron, manganese, tantalic acid, or silica. Colour white, but usually grey, and sometimes red, yellow, brown, and black, with a resinous, semi-metallic lustre. This ore has a variety named *stannite*, which has only 36·5 of tin oxide, with alumina and silica.

Tin Pyrites (*Sulphide of Tin*).—A rare ore, called in Cornwall, where alone it is said to be found, *bell metal*. Chemical composition: tin, 27, sulphur, 30, copper, 30, iron, 13.

In workable quantities it is far less universally distributed, geographically, than the metals we have already considered, and hence the localities we shall have to notice will be very much fewer. Like gold it occurs both in rocks and also in alluvial deposits formed by the wearing down of its containing strata. We will begin our notice of its distribution, and the modes of its occurrence in nature, in the far East.

BANCA.[1]—Tin is found to a limited extent in China, and in several of the islands of the Malay Archipelago, but it is worked to the greatest extent in the island of Banca, in the superficial drift of which tin was discovered in the year 1710. So far the tin has been derived exclusively from these deposits, and the position in which it is found is shown in fig. 64.

FIG. 64.—SECTION OF THE ALLUVIAL TIN DEPOSIT, BANCA.
Underlying rocks, granite, 1, and metamorphosed slates and sandstones, &c., 2.

The mining, or excavation, is of the simplest kind, and the manner of working will be described further on.

The tin ore is accompanied with fragments of the rock from which it was originally derived. This is granite, with a large admixture of schorl and sandstone. The alluvial tin is very pure, as the following analysis will show :

Tin	99·961
Iron	00·019
Lead	00·014
Copper	00·006
	100·000

Both in Banca and on the island of Billiton the alluvial tin

[1] *Bangka Beschreven in Reistogen*, door P. Van Diest, Mijn-Ingenieur, 1865. (English Translation by Dr. C. Le Neve Foster, Truro, 1867.)

has been traced to its source in the parent rocks forming the hilly country. The central rock is granite, covered by quartzites, altered sandstones, and slaty rocks. Quartz veins, containing mica, also traverse the granite and the immediately overlying rocks, and these contain varying proportions of tin, wolfram, and manganese. Large lumps of tin ore, averaging 40 per cent., also occur, weighing from 100 to 140 lbs. The altered sandstone, just above the granite, is the most productive rock, and it is traversed in all directions by thin veins of tourmaline, and of clay containing tourmaline. Tin occurs in the granite, and in the rocks overlying it, over a large extent of Northern Banca. It occurs in small veins and bunches in the joints and along the planes of bedding. Hitherto no profitable tin mining in the solid rock has been made in the island. In the Malayan

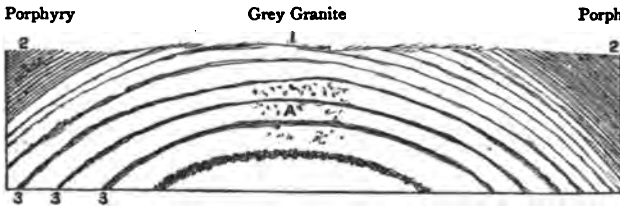


FIG. 65.—SECTION OF STRATA WITH TIN ORE, ZINWALD.

Peninsula, tin diggings have been worked by the Chinese since the year 1793. The mines are swampy flats at the base of the hills. The ore seems to follow depressions in the drift for several miles in length, and these are known as streams of ore. The tin derived from this eastern region is known in commerce as 'Banca,' 'Straits,' and 'Billiton.' The production in 1876, according to the sales in Batavia, was 17,683 tons.

AUSTRIA.—A little ore has been found in the districts of Penonta and Romilo, in the provinces of Orense and Pondevedra, in Gallicia. The ore occurs near the junction of granite with micaceous and hornblendic slates.

BOHEMIA.—The great deposits of tin lie in the Erzgebirge range of mountains, whose geological structure I have

already described. One of these, the Zinwald,[1] is partly in Bohemia.

Fig. 65 is a diagram section through the rocks in which this deposit lies.

The granite, 1, is overlaid on all sides by porphyritic rock, 2. In the granite are roughly bedded layers, 3 3 3, consisting of quartz, mica, and oxide of tin, mixed with other minerals. These layers seem to converge towards the centre of the mass,

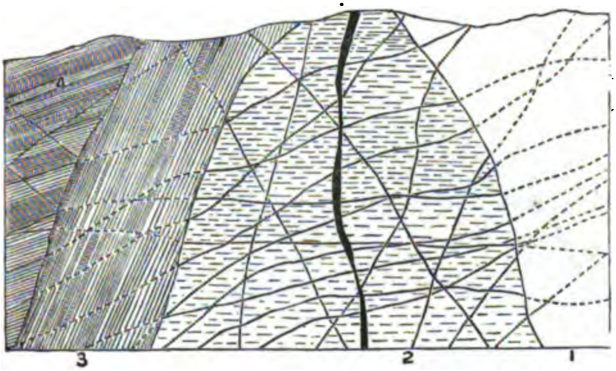


FIG. 66.—SECTION OF TIN STOCKWERK, ALTENBERG.

and in places, as at A, the mass of the rock is richly impregnated with tin ore.

GERMANY : *Saxony*.—On the Saxon side of the Erzgebirge, or near the boundary between the two countries, are other important tin stockwerks, two of which I will describe.

Fig. 66 is a section through the strata, in which the stockwerk of Altenberg[2] is worked. 1 is a mass of porphyritic granite, in which the crystals of felspar are very large. 2 is a mass of fine porphyritic rock, of a dark grey colour, passing in places to a reddish grey, and more rarely into a clear grey colour. The structure is not the same throughout, quartz being present in places. The mass is about 400 yards long by 300

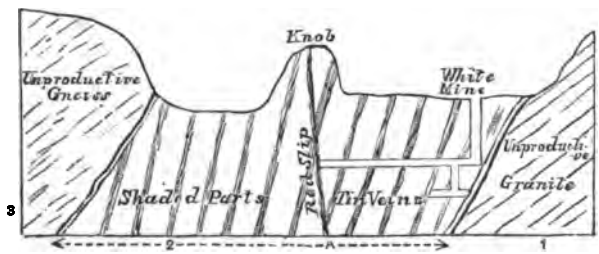
[1] Weissenbach, *Merkwürdige Gangverhältnisse;* D'Aubisson de Voisins, *Traité de Géognosie.*

[2] D'Aubisson de Voisins, *Traité de Géognosie.*

yards wide. 3 is a mass of syenitic porphyry, varying in colour from a light to a brown red, which contains numerous crystals of hornblende, and in places groups of crystals and grains of quartz. 4 is a variety of porphyry that approaches more nearly in composition to the central mass 2.

The whole of these beds are traversed by a network of fine flexuous veins, which vary from one to several feet in width; and these are cut nearly vertically through by a larger and more recent fissure A (fig. 67), which is partly filled with the *débris* of the enclosing strata set in a matrix of ferruginous clay.

The network of veins are also filled in like manner, and all, through their course in the rock 2, are more or less charged with tin. Those that have a direct east and west direction are richest. The same is true of the points of intersection. The



Productive Granite

FIG. 67.—TIN STOCKWERK OF GEYER: SECTION THROUGH IT.

tin also penetrates the adjoining rock to a distance of several feet. Indeed, the whole mass 2 is impregnated with tin, especially where quartz prevails. This is also true of the rock 4, and to a less extent of the rock 3.

The lodes are productive in the rock 2, but lose their tin as they enter the porphyritic granite 1, on the one side, and the syenitic rock 3 on the other. They regain their metallic contents to some degree in the rock 4, in the parts where quartz enters into its composition.

Another important tin stockwerk of the Erzgebirge is that of Geyer.[1] It lies on a circular truncated mass of fine-grained

[1] D'Aubisson de Voisins, *Traité de Géognosie.*

micaceous granite, 1, fig. 67, which is covered on all sides by a gneissic rock, 3. The granite graduates into the gneiss, and the junction forms a circular belt of stanniferous rock, 2, which forms the stockwerk.

This belt, 2, forms a granite different from the centre mass, 1. The quartz and felspar are formed of fragments from two to six inches long, and from a quarter of an inch to two inches thick. Red felspar predominates. The quartz is splintery, crystalline, and compact, and sometimes occupies large spaces. Mica is also present in nests and fragments.

The whole mass is traversed by vertical veins and horizontal layers charged with tin. The veins are of variable width, and the thinnest do not extend far, rarely passing beyond the granite. The strongest are most regular and persistent, and pass into the granite, and also into the surrounding gneiss. As a matter of observation it is found that the true east and west veins are richest in tin, and the points of the intersection of the veins are productive of the mineral. The granite itself is impregnated with tin, but contains the least where the veins are less frequent.

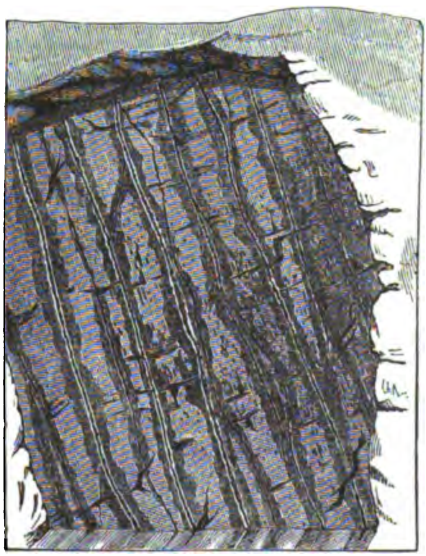


FIG. 68.—VEINS IN STOCKWERK OF GEYER, SHOWING CENTRAL VEINS AND DECOMPOSED ROCK ON EITHER SIDE OF THE SAME.

In quarrying the mass the veins show for the most part a parallel vertical appearance. Their intimate structure is shown more minutely in fig. 68. The centre of the vein is mostly

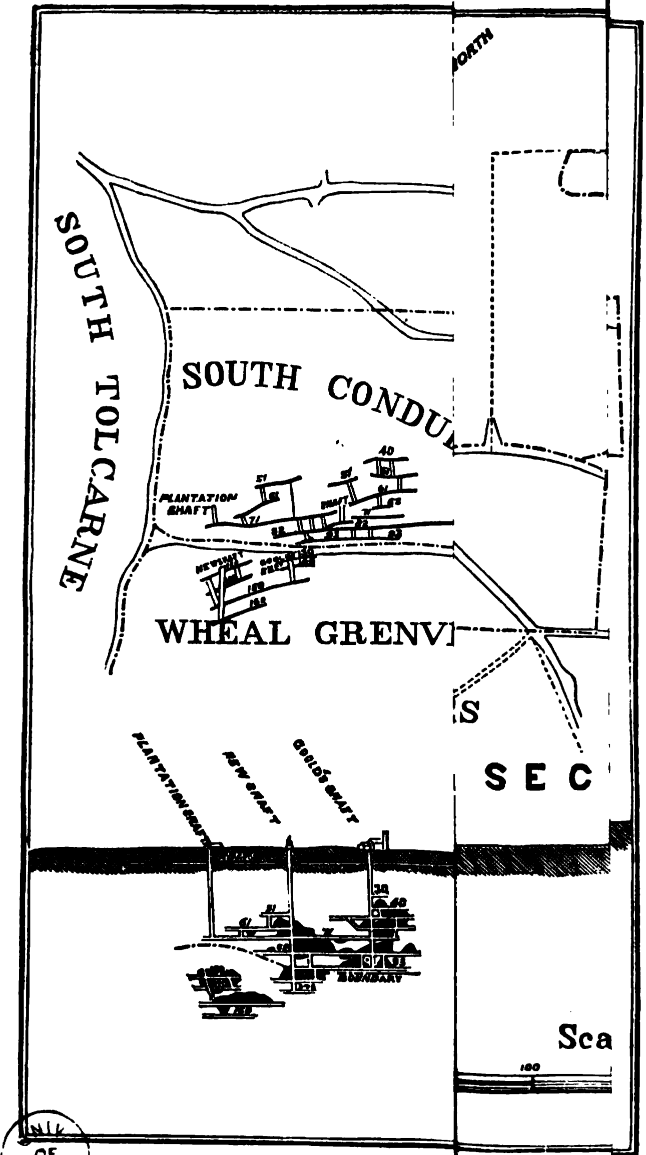
filled with quartz, and fragments of the adjoining rock with tin ore. The dark shading shows how the rock has become partly decomposed and recrystallised for some distance on either side, and this portion adjacent to the vein is interspersed with grains of ore. The veins in the figure lie about fifteen inches apart. The deposit has been worked to a depth of between 400 and 500 feet.

The annual production of tin in Austria and Germany is estimated at not more than 200 tons; but the deposits have more scientific than commercial importance.

FRANCE.—There are the traces of ancient tin mines and detrital tin works in the neighbourhood of Auvergne, in the southern part of Central France.[1] Attempts have been recently made to revive this branch of mining industry in the region. These so far have been unsuccessful, but a brief notice of the district will be useful for comparison. There are great masses of granite of two kinds, the oldest of which has its mica all black, the newest has both black and white mica. Against these erupted granites lie, first crystalline schists, next gneiss, and then mica slate. The whole series with the granites is traversed by veins or lodes. Tin ore, when found, usually lies on the sides of the veins, and the granite is often, for some distance from the crack, decomposed, the felspar having given place to clay. With the tin ore in the lodes there are associated wolfram, mispickel, native copper, arseniate of iron, fluorspar, sulphate of barytes, more rarely phosphate of lime, and more rarely still grains of gold. Detrital tin has been worked in the gravels overlying the granites.

SWEDEN.—This country produces about 200 tons of tin ore yearly, but we lack information concerning the character of the deposits, and pass at once to consider the tin mines and deposits of the British Isles.

[1] *Ann. des Mines*, 6e série, 5e liv.—Mallard, 'Note sur les Gisements du Limousin et de la Marche.'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IES ON THE.

CHAPTER XXI

TIN—continued.

Tin in the British Isles—Cornwall—Importance and Antiquity of the Industry—Brief History of Tin Mining in the County—The Great Flat Lode—Cligga Point—Remarks on the Depths of Mines, and on the particular Structure of the Tin Lodes of Cornwall.

THE BRITISH ISLES : *Cornwall.*—The raising of tin ore formed one of the earliest of British industries, and helped to form the foundation of the commercial character of the country. Diodorus Siculus, 60 B.C., describes the tin trade of these islands; and St. Michael's Mount, Cornwall, is supposed to be the market where it was carried on. The industry belongs to Cornwall, and to a very little extent to the contiguous part of Devon. Up to the eleventh century it is probable that the whole of the tin raised was derived from 'stream works' and the washing of stanniferous sands and clays. About the date named lode mining for tin is believed to have been begun. The tin mines of Cornwall were, in the reign of King John, farmed for 100 marks per annum, which amount was increased in the next reign, when we find the Jews engaged in them, from which circumstance it is probable that the industry was then of a lucrative nature.

The tinners petitioned Edmund, Earl of Cornwall, by the Lords of Blackmore, for a charter that should define their rights.[1] This was granted, and confirmed by Edward I., in the thirty-third year of his reign. This charter conveyed the right of holding a court—the Stannaries Court—for the consideration and settlement of all disputes and matters relative to tin mining. This tinners' parliament was allowed to be convoked at discretion,

[1] Carew, *Survey of Cornwall*, p. 17.

and the charter gave the right to each tinner to sell his own tin, unless the king wished to buy; also the right of cutting turf on the king's lands for smelting. For these privileges the tinners were to pay a duty of one halfpenny for every pound of tin manufactured. To secure the payment of the duty, all tin was to be brought to certain towns at Midsummer and Michaelmas to be weighed, and kept until the duty was paid.

In the reign of Henry VII. his son Arthur made some obnoxious regulations for the Stannaries, which the tinners refused to obey, and which provoked them to breaches of the law. On the death of his son, the king made this conduct an excuse for cancelling the charter, and for taking the mines into his own hands.

Not finding mining profitable, he gave the mines back to the tinners, with the further important concession that no law relating to the tinners should be enacted without the consent of twenty-four gentlemen—tinners—six to be chosen by a mayor and council in each of the four Stannary divisions.

In the time of Elizabeth the production was about 700 tons a year, and the price from 45*l.* to 50*l.* per ton. In the reign of James I. the make of block tin in Cornwall amounted to about 1,500 tons a year. The production was about the same in the time of George I. About the year 1742 it had increased to 2,000 tons, and from 1750 to 1778, the production was estimated at 3,000 tons a year.[1]

The total production of tin ore in Cornwall and part of Devon for the year 1877 was 13,995 tons 10 cwt., of the value of 575,604*l.* 5*s.* 1*d.*

The production for the previous year was 14,004 tons 17 cwt. 0 qrs. 13 lbs., of the value of 700,514*l.* 5*s.* 2*d.* It will thus be seen that, while the production in 1876 was only 355 tons less than the year before, the value was, owing to depreciation in price, less by 124,910*l.*

The ore was derived from 183 mines, inclusive of 27 stream works. Of this number, 174 mines proper were situated in Cornwall, and 9 in Devon. Of the 174 Cornish mines, 100,

[1] William Pryce, *Mineralogia Cornubiensis.*

producing 10,501 tons of ore, were situated in the western half of the county. The mineral results thus agree with the general description of the characteristic mineral features of the county given in the description of its copper deposits. In 1879 the production of tin ore (black tin) was 14,280 tons 8 cwt.

The tin deposits of Cornwall have been described by many able observers,[1] and all the works mentioned in the note below are full of information concerning them.

One of the latest observers is Dr. Clement Le Neve Foster, F.G.S., one of H.M.'s Inspectors of Mines. In the course of his official duties, Dr. Foster has had many opportunities of studying the characteristics of and acquiring information concerning the lodes of Cornwall. The observation of these characteristics has accorded with his tastes, and he has brought to the work the ability resulting from culture and practice. I do not think, therefore, that I can do better than avail myself of his generous permission to use his descriptions and illustrations of the tin lodes of Cornwall which have appeared in several of his communications to learned societies.

Let us begin by noticing the structure and character of the *Great Flat Lode*, south of Redruth and Camborne.

This lode extends from the Perseverance Mine on the east to South Tolcarne on the west, and runs along the south side of the granite mass of Carn Brea.

Fig. 69, prepared by Dr. Foster[2] and Mr. Thomas B. Provis, affords a plan of the mines wrought upon it, and a section of their workings.

The dip of the lode is much flatter about 30 to 50° south than the average dip of the tin lodes of Cornwall, which is about 70° from the horizon. It also varies in width, structure, and character, as the following illustrations from observations by Dr. Foster will show:

[1] Pryce, *Mineralogia Cornubiensis*; De la Bêche, *Report on Devon and Cornwall*; Fox, *On Mineral Veins*; Henwood, Carne, and others, in *Transactions of the Royal Geological Society of Cornwall*; Moissenet, *On the Lodes of Cornwall*; Salmon, in *Mining and Smelting Magazine*, &c.

[2] *Quarterly Journal of the Geological Society*, August 1878.

Fig. 70 is a section of the lode at Wheal Uny Mine, in a stope above the 110 fathoms level.

A is the leader, or original crack, from 2 to 10 inches wide, which is filled by fragments of chloritic slate, cemented by quartz and iron pyrites. B B is a variable thickness of fine-

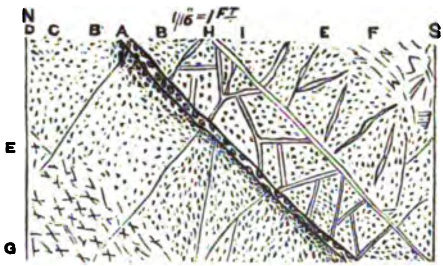


FIG. 70.—SECTION AT WHEAL UNY, ABOVE THE 110 FATHOMS LEVEL.

grained or compact schorl rock, with strings and spots of quartz and tin ore; H is a clay vein, containing a little quartz and iron pyrites; C is similar to B, and contains 4 inches of tinstone under the leader I. E and E are capels consisting of compact schorl

$\frac{1}{16}$″ = 1 foot.

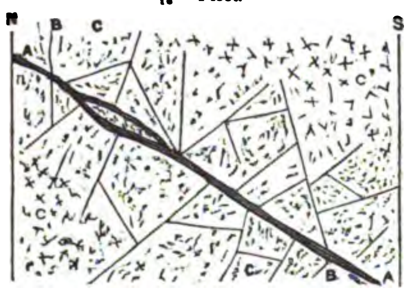


FIG. 71.—SECTION AT WEST WHEAL BASSET, ABOVE 104 FATHOMS LEVEL.

rock, the upper one showing the material arranged in layers; G granite; F killas, or slaty rock. The lode at this point lay, it will be seen, between the granite below and the killas above, into each of which it gradually passed without any dividing wall from the central leader or crack. Fig. 71 represents the structure

of the lode at West Wheal Basset Mine, at a depth of 104 fathoms.

A is the leader, 2 to 3 inches thick, filled with fragments of capel; B B consists of stanniferous schorl rock of bluish grey colour, passing into C C, an unproductive schorl rock (capel),

FIG. 72.—SECTION AT SOUTH CONDURROW, ABOVE 83 FATHOMS LEVEL.

with large grains of quartz set in a black matrix, a kind of rock always unproductive. The combined thickness of B and C above the leader is 9 feet, and 6 feet below it. The unpro-

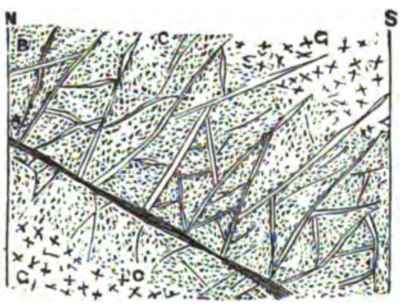


FIG. 73.—SECTION AT SOUTH CONDURROW, ABOVE 93 FATHOMS LEVEL.

ductive rock passes gradually into the granite G G, which here encloses the lode on both sides. Another variation in the structure of the same lode is seen at South Condurrow Mine, as represented in fig. 72.

A is the leader, filled with clay, much quartz, and oxide of iron,

and fragments of the adjacent rock; B is the tin-bearing rock, about 5 feet thick, consisting of compact stanniferous schorl rock, black and slaty in colour, traversed by numerous quartz veins of all sizes up to 2 or 3 inches wide, and little cross veins besides vertical joints filled with iron pyrites. This passes into C C, compact schorl rock (capel); with veins and spots of quartz, and little or no tin, it fades into the granite G G. At South Carn Brea, at a depth of 175 fathoms, the leader, which there was from 2 to 4 feet wide, was charged with copper ore. Here it lay between the granite below and killas above. In places, as at West Wheal Basset, the whole of the schorlaceous rock, capel included, is stanniferous, and expands to a width of about 50 feet. Fig. 73 shows another variation of the lode at South Condurrow.

The whole of the stanniferous portion of the lode is taken out, and the following figures will show the proportion of tin stuff and clean tin ore produced in 1876 by six of the mines on the lode:

Name of Mine	Tin stuff	Clean tin ore
	Tons	Tons
Wheal Uny	17,702	349
South Carn Brea	2,040	30
West Basset	29,144	618
West Wheal Frances	6,652	123
South Condurrow	19,414	588
Wheal Grenville	8,500	138
Total . . .	83,452	1,846

The clean tin ore was therefore about 2½ per cent. of the ore raised, and the lode altogether yielded over one-eighth of the total quantity raised in Cornwall.

We will next take a few illustrations of the structure of other tin lodes in the county.

Fig. 74 represents a plan of a pipe of ore at East Wheal Lovell Mine, near Redruth.

A B is the original crack or leader, from a quarter to half an inch thick, filled with quartz and ferruginous clay; C C shows the

tinny mass that gradually passes into the granite D D. The granite D contains large crystals of orthoclase. The tinny mass C C is made up of a mixture of quartz, mica, gilbertite, fluorspar, iron and copper pyrites, and cassiterite, or tinstone. Sometimes the tin ore inclines more to one side and again to the other. This pipe of ore varies in length from 12 to 36 feet, and in breadth from 9 to 12 feet. It has been followed down from the 40-fathom level to the 110 as one continuous pipe. In places, when tin was selling at 80*l.* per ton, it was worth from 800*l.* to 1,000*l.* per fathom, and generally gave from 5 to 6 tons per cubic fathom.

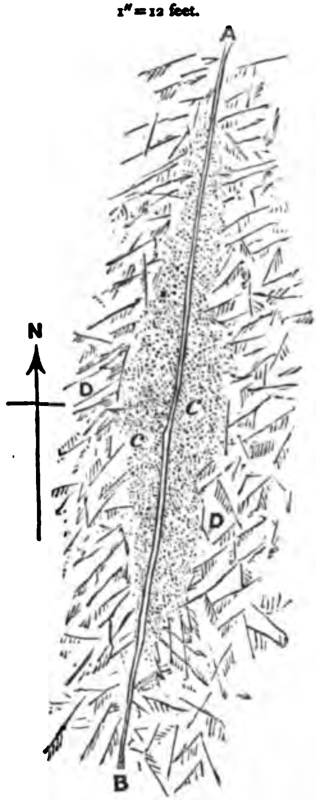


FIG. 74.—PLAN OF LODE AT EAST WHEAL LOVELL MINE, REDRUTH.
A B, Tin lode. C C, Ground impregnated with tin ore. D D, Granite.

The East Wheal Lovell lode occurs in granite, but the next illustration, fig. 75, shows the occurrence of tin ore along the lines of bedding of slates at the Park of Mines, south of St. Columb. The slates lie, however, in proximity to the great granitic mass north of St. Austell.

The slates dip at an angle of 70 degrees to the north, and numerous lenticular masses of tin stone occur along the lines of bedding. There are also thin veins of one to two inches, containing tinstone crossing these deposits. The bedded tinstones range from one to two inches thick, occasionally expanding to a thickness of one foot.

They run about 7 fathoms from north to south, and about 10 fathoms down the dip. The tin ore is associated with quartz, schorl, and kaolin.

The granitic mass of Cligga Point will furnish us with a Cornish equivalent of the stockwerk of Geyer. This mass is about 300 feet high, and it is traversed by a great number of nearly parallel veins, as shown in fig. 76, which also affords a nice illustration of lodes displaced by a fault.

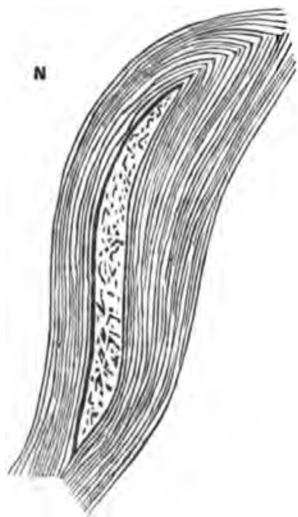


FIG. 75.—TIN ORE ALONG THE LINE OF BEDDING IN SLATES NEAR ST. COLUMB.

The veins dip north at angles from 65 to 80 degrees. Fig. 77 gives a view of the intimate structure of one of these veins.

1 1 is a vein of quartz three inches wide, in which the crystals starting from each wall sometimes meet in the middle, and some times leave a vugh or open cavity, containing, as does also the quartz, cassiterite, wolfram, mispickel, and schorl. 2 2 is a band of dark rock—'greisen'—four inches wide on both sides of the quartz vein. This rock is quartz and mica, or granite without the felspar, and contains schorl, gilbertite, and small quantities of tinstone. Acicular crystals of schorl frequently fill up the cavities apparently left by the removal of orthoclase. This rock graduates into the adjacent granitic rock 3 3. The width of the veins varies from half an inch to six inches wide, and they lie from a few inches and a few feet apart.

It may here be observed generally that tin is sometimes in Cornwall mixed up with iron in the gossan overlying a copper lode, when it is considered by the miners a good sign for copper below. When mixed up with copper in a lode, tin usually pre-

vails on the upper side, although it is occasionally found under the copper. When so found the tin and copper are divided

Scale $\frac{1}{16}$.

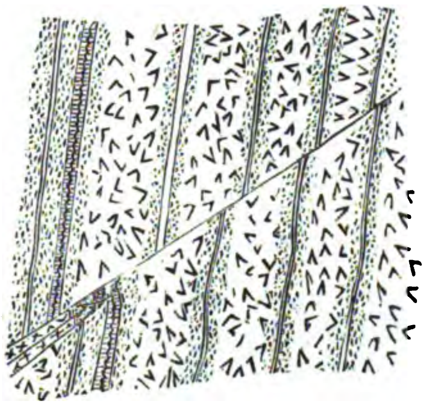


FIG. 76.—SECTION OF GRANITE, WITH VEINS OF TIN ORE, CLIGGA POINT, CORNWALL.

from each other by parallel layers of quartz, clay, and other earthy minerals. When tin and copper occur in the same lode

Scale $\frac{1}{3}$.

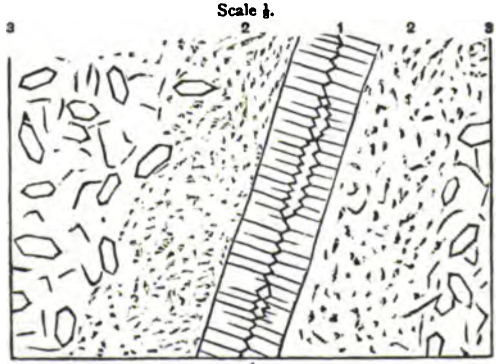


FIG. 77.—ENLARGED VIEW OF VEINS IN GRANITE AT CLIGGA POINT.

on opposite sides an increase of one ore on one side is usually accompanied by an increase of the other on the other side. If

the ore on the foot wall diminishes it is considered an unfavourable sign; if it increases, it augurs well. When lodes traverse beds at right angles to the dip of the latter the ore masses have a shoot or inclination corresponding to the dip of the beds.

A hard black gossan yields some tin, but the mineral is not easily worked to profit in it, nor does it often occur in a satisfactory state in a peachy lode. In pryany lodes tin often occurs in grains of fine quality. These lodes are really detrital deposits, cracks into which materials have been washed: hence the similarity of the ore to stream tin. The best lode is a scovan, so called because it is composed almost exclusively of tin ore. The rocks in which tin lodes are most profitable are,

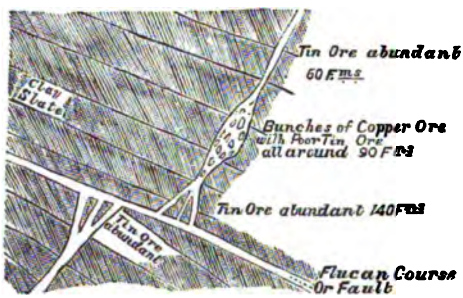


FIG. 78.—SECTION OF LODE AT OLD HEWAS MINE, CORNWALL.

as we nave seen, the half-decomposed schorlaceous granite, and the immediately overlying slaty rocks or killas where these are of a brown or reddish colour.

The depth at which tin may be profitably worked depends chiefly upon the nature and dip of the strata. It is worked to great depths in granitic rock of a favourable kind, and in killas where these dip at a great angle, and where they are overlaid with newer strata. Its stratigraphical place and profitable zone occurs below that of copper, but there is of course, as we have seen, a dovetailing of the two minerals vertically. Thus at Old Huel-Vivian a tin and copper lode was wholly in granite; the lode varied from 2 to 40 feet wide, contained large angular masses

of granite, with yellow copper ore and tin lying between them. It was crossed by eleven cross-courses in 170 fathoms, and the lode was most prolific near the points of intersection. We may take this lode as an example of many other mechanically formed lodes into which both metals were washed from their parent rocks at a date subsequent to that of the origin of most of the true tin lodes we have been considering. Old Hewas Mine gave a good example of richness at the point where the lode was crossed and broken by a cross-course. Fig. 78 is an illustration of this. Tin lodes often increase in productiveness also near their junction with elvan courses or felspathic dykes crossing them.

CHAPTER XXII.

TIN—continued.

Alluvial Tin Deposits of Cornwall—Tin in Bolivia, Queensland, New South Wales, Victoria, and Tasmania—General Deductions and Concluding Observations.

WE may now pass on to notice the alluvial tin or stream tin deposits of Cornwall. These are of two kinds: first, natural deposits, in which detrital tin brought down from its parent rocks on the higher lands has settled down in river streams and valleys; and, secondly, the deposits where fine tin ore escaping from the dressing-floors of mines has settled down in the bed or on the banks of a stream where conditions were favourable. It is with the former we have chiefly to do now.

In the year 1877 there were 27 stream tin works in Cornwall. Of these 18 were on the Red River, and 9 on the tributary that, running down from Carnbrea and Tincroft, joins this river at Tehidy Mill. The amount of tin raised from this source in 1877 was 753 tons 4 cwt. 2 grs., or about one-fifteenth of the total amount raised in Cornwall and Devon. About 800 persons are employed at these stream tin works, whose combined earnings are given at 1,500*l.* per month.

Formerly alluvial tin works were spread over large portions of the lowlying lands of Cornwall, along the estuaries of rivers, and on the seashore. The following selected sections will give some idea of the ground enveloping these tin deposits.[1]

[1] Quoted by De la Bêche, *Report on the Geology of Cornwall and Devon.*

Section of tin ground near the Par estuary, taken by Captain Barratt:

	Feet	Inches
1. River deposits	1	6
2. Irregular mass of mud, sand, clay, and stones	7	0
3. Old surface of mud, clay, and vegetable matter	8	0
4. Fine sand, with sea shells, and on the top rolled pebbles	4	0
5. Mud, clay, sand, woodnuts, and other vegetable matter	3	0
	23	6
6. Tin ground resting upon an uneven surface of slate	0	6 to 6 feet.

Section of the Carnon stream works, taken by Mr. Henwood:

	Feet	Inches
1. Sand and mud, river wash	3	0
2. Silt and shells—three successive beds	0	10
3. Sand and shells, with a stream of fresh water	2	0
4. Silt—three beds	12	0
5. Sand and shells . . . . 3 feet 10 inches to	4	0
6. Silt largely mixed with shells	12	0
7. Silt in some places containing stones . . 18 feet to	22	0
8. Wood, moss, leaves, nuts, &c., a few oyster shells, with the bones of deer and human remains	1	6
	59	4
9. Tin ground . . . varying from a few inches to	12	0
10. The shelf or rock of dirty white and pale blue slate		

The bed 8 sometimes disappears when bed 7 rests immediately upon the tin ground. The latter consisted of rounded masses of tin ore, in places unmixed, and in others contained in a matrix of quartz and quartz and schorl associated with rounded pieces of slate, granite, and quartz.

Other sections show a similar succession of beds, and contain the vegetable bed immediately above the tin ground. The presence of this bed in this position shows the very recent date of the overlying driftal matter, and leads to the following theoretical inquiries. Was the detrital tin only deposited just before this recent vegetable deposit, or, as its rounded character would indicate, was it a vastly older deposit? If the

latter, had it remained exposed on the surface for ages, or had it been covered with older drift of glacial times, which had been denuded before the deposition of the recent vegetable bed? Probably the latter supposition is nearer the truth, in which case the tin deposit belongs to the age of those local preglacial drifts whose place is everywhere in the hollows of the solid rock, and which are in their turn covered usually by the lower boulder clay or some other member of the glacial series. Such inquiries have, however, more interest for the speculative than for the mining geologist, and I pass on.

No discovery of tin ore of any importance has hitherto been made in North America. In South America it has been mined to some extent in Bolivia; but I now proceed to notice the recently discovered important deposits of the mineral in Australasia.

QUEENSLAND.—Beginning on the north with Queensland, the discovery of tin in this colony was reported by the Government in the year 1872.[1] The stanniferous country lies between the head waters of the Condamine River on the north, and the boundary of New South Wales on the south. It comprises an area of about 550 square miles, of which about one-half has been proved ground sufficiently rich in ore to pay for working. The higher part of this region consists of an elevated granitic tableland, intersected by ranges of abrupt hills, some of which rise to the height of 3,000 feet above the sea. Several rivers have their rise in this elevated country, and force their way through deep narrow gorges to the open country below. Among these are the Clarence, Condamine, Severn, and Macintyre. It is along the course of the River Severn, from near its source down to Ballandean, a distance of 140 miles, that the principal alluvial tin deposits are found. There are also 30 miles of rich tin ground along the tributaries of Pike's Creek.

The richest deposits lie in the stream bed, and on the flat ground of both banks of the Severn, and they extend to a distance varying from a few to one hundred yards on both sides.

[1] Gregory, 'On the Discovery of Tin in Queensland,' *Quarterly Journal Geological Society*, vol. xxix. p. 1.

These two belts are broken across by rocky ridges, but tin ore has been largely accumulated in the hollows lying in and between these barriers. The quantity of tin ore contained in this river belt reaches as high as 30 tons to the chain in length, and its average yield is estimated at 10 tons per chain (22 yards).

Two principal tin lodes have been discovered *in situ*, near Ballandale Head Station. The rock here is a coarse-grained granite, which soon disintegrates on exposure to the atmosphere. Mixed up with this granite are numerous bands of loosely aggregated granitoid rock, containing much mica, and traversed in all directions by bands and veins of quartz.

In these bands crystals of tin ore, *cassiterite*, are abundant. They are generally found imbedded in and along the margin of the quartz veins and bands, and also occasionally in the midst of the mica, which, when such is the case, is invariably white in colour. The strike of these quartz veins and bands is NE. by SW. Other smaller veins have been discovered, but so far little or no attention has been paid to mining for tin in the solid rock. The quantity of stream tin raised in the year 1874 is given as 5,585 tons 6 cwt. 3 qrs. and 9 lbs.

NEW SOUTH WALES.[1]—The same geological conditions are continued southward into this colony, near the northern boundary of which, Mr. D. Brown, of Sydney, claims to have first discovered tin ore among the stuff thrown out of an old saw pit. The discovery of tin ore in the colony was first brought into notice in this country by a communication made to the Geological Society in December 1871, by Mr. G. M. Stephen, F.G.S., of Sydney.

The ground on which Mr. Brown's discovery was made afterwards became the property of the Elsmore Tin Mining Co., and it will afford us the best illustration, perhaps, of the mineralogical conditions in which the ore occurs. The land lies on the north-west side of the Macintyre River. It is intersected by a granitic range, 250 feet high and nearly two

[1] 'Observations on some of the Recent Tin Ore Discoveries in New South Wales, by G. H. F. Ulrich, *Quarterly Journal Geological Society*, vol. xxix. p. 5.

miles long. The granite is micaceous, and contains crystals of white orthoclase, which are often several inches long. More rarely the orthoclase is bluish grey in colour. This granite is traversed by quartz veins from four to five inches wide, in which, in fine druses, seams, and single crystals, tin ore occurs. The quartz of these veins gives place occasionally to a micaceous greisen-like rock.

Besides these quartz veins, the great mass of granite is traversed by dykes of softer granite, three-fourths of which consists of mica, and the remaining fourth of felspar, without much quartz. In these micaceous dykes, tin ore is plentifully distributed in grains from the size of a pea downwards, and also in irregular veins several inches thick, and in nests and ramifications, which often yield lumps of nearly pure ore in all sizes up to 50 pounds in weight.

One of these dykes, of which there are at least six in the property, forms a regular breccia of mica and partly crystallised tin ore, cemented together by hydrous oxide of iron.

It is from the disintegration of such dykes and stanniferous masses that the rich alluvial deposits of tin, that nestle in the lowlying lands and along the banks of the streams, are derived, for with the tin ore in such deposits are found fragments and grains more or less worn of the original enclosing rocks. Thus far tin mining has been confined to alluvial workings, the particulars of which for the year 1876 are thus enumerated by the *Mining Registrar*:[1]

Locality	Number of miners	Ore	Value
		Tons	£
Tingha	500	2,300	69,000
Glen Innes	120	1,000	30,000
Vegetable Creek	625	3,008$\frac{14}{20}$	90,261
Tenterfield	407	1,055$\frac{16}{20}$	40,352
Tumbarumba	2	12	660
Tenterfield Tin Ingots . .	—	330	22,440
Total . . .	1,654	7,706$\frac{1}{2}$	252,713

[1] *Report of the Department of Mines, New South Wales.*

VICTORIA.—Proceeding south into the colony of Victoria, tin is found near the boundaries of the granitic masses of Beechworth and Berwick, in the county of Mornington. The Beechworth mass of granite is fine grained and highly felspathic, but it contains portions highly micaceous, like the Saxon and Cornish 'greisen.' In these portions tin ore is found associated with stanniferous sand.

In the gravels and alluvial deposits surrounding these granitic masses tin ores are found, and they are often associated with gold.[1] The pure ore from Woolshed Creek contains 78 per cent. of tin and 22 per cent. of oxygen. As sold the ore assays about 53 per cent., being mixed with titaniferous iron ore and other substances. In the desire of the miners to obtain gold it is to be feared that tin ore has been much neglected. The exports of tin for the year 1877 were only 34 tons 9 cwt.

TASMANIA.—Farther south, tin ore has more recently been discovered at Mount Bischoff, in the NW. portion of this island. Mount Bischoff rises from the western side of the basaltic plateau of the Surrey Hills to a height of 2,500 feet above the sea. It is described[2] as a porphyritic rock containing granules and crystals of quartz and felspar. It weathers white, and is honeycombed on the surface from the decay of pyrites, which are abundantly disseminated in it. On its western and southern sides it is overlaid by metamorphic and contorted schists. Veins and strings of tin ore—oxide of tin—traverse the rock, and tin ore occurs in the joints.

There are also gossany outcrops of larger lodes, and irregular deposits of great extent in which are minute particles of tin stone. Larger lumps up to 400 and 500 lbs. weight of rich tin stones also occur.

From the disintegration and denudation of these rocks, tin ore fills the troughs and hollows of the mountain side: hence the hill has been called a mountain of tin ore. Similar

[1] Brough Smyth, *Gold Fields, &c., of Victoria.*

[2] Gould, 'On a Recent Discovery of Tin Ore in Tasmania,' *Quarterly Journal Geological Society*, vol. xxxi. p. 109.

discoveries have still more recently been made farther south, at Mount Heemskerk, on the west coast. The amount of tin exported in 1873 was estimated at 7,000*l.* In 1877, the estimated value of the tin exported is stated at 280,000*l.*

In reviewing the foregoing description of the tin deposits of the world, we are impressed with the great uniformity of the geological and mineralogical conditions under which it occurs *in situ*, as these have been described at widely different times by widely different observers.

Its home is in granite, which, underlying, as it is seen to do in Banca, Germany, France, Britain, and Australia, the oldest known sedimentary rocks, belongs evidently to the Laurentian series, if not to an earlier primitive group.

It abounds most in granite of a peculiar type, from whose composition felspar is largely absent and mica largely present. Everywhere it is accompanied by schorlaceous conditions of the rock. Were these granitic dykes thrust through the older granite with their enclosed minerals? or do they lie along the lines of ramifying cracks, up which vapours charged with stanniferous matter have come, dissolving the felspar and leaving its mineral burden of tin behind, just as we see has been the case in the stockwerk of Geyer, fig. 68, in the thin lodes of Cligga Point, Cornwall, figs. 70 and 71, and in the ore pipes of East Wheal Lovell, fig. 74?

Geologically, the correlation of the granites of Cornwall with the other tin-bearing granites of the world, fixes, I think, the age of the former, and confirms my inference, before stated, that the older and tin-bearing slates and metamorphic rocks of that county are nearer Cambrian than Devonian age.

CHAPTER XXIII.

LEAD.

Native Ores of Lead—Lead Ores of Austro-Hungary—Banat—Carinthian Alps—Bleiberg—Germany—Erzgebirge—Hartz—Clausthal and Zeller—Nassau—Rhenish Provinces—Spain—Brief History—Andalusia—Sierra de Almagrera—Linares—Hornachos—France—Pontgibaud—Poullaouen—Bretagne—Belgium.

THOUGH of less money value, owing to its wider distribution in nature, this metal, whether used alone or in combination with other metals in the shape of alloys, is one of the most useful of all the metals. In colour it is of a bluish grey, it is easily fusible, it is soluble in nitric acid, and is very malleable. The chief forms in which it occurs in nature are the following:

NATIVE LEAD.—Very rarely the metal occurs in this form, but it has been found native in the mines of Alston Moor, in meteoric iron in Chili, in lava in Madeira, in clay slate at Carthagena, and near Kenmare in Ireland. In this form its hardness is 1·5, and its gravity 11·3 to 11·4.

SULPHURET, OR SULPHIDE OF LEAD.—GALENA.—This is the most plentiful ore of lead. Chemical composition: 86·55 lead, and 13·45 sulphur. It usually, however, contains, as we have seen, a little silver, with varying small proportions of copper, zinc, or antimony, when of course one or both of the chief constituents are displaced to some extent. Gravity, 7·2 to 7·6.

In combination with other substances we have the following varieties of this ore:

Clausthalite, mixed with selenium in varying proportions, and giving a horse-radish odour when fused. Hartz mountains.

Cobaltic lead ore, mixed with arsenic, and with a trace of cobalt. Hartz.

Cuproplumbite, containing 24·5 per cent. of sulphide of copper. Chili.

Dufreynoysite, with a proportion of arsenic, of a dark steel grey colour. Dolomite of St. Gothard.

Telluride of lead, of a tin-white colour, and cleavable. Altai Mountains.

Tellurium-Foliated.—Chem. com.: 32·2 tellurium, lead 54·0, gold 9·0, with silver, copper, and sulphur. Transylvania.

OXIDE OF LEAD.—MINIUM.—RED LEAD OF COMMERCE.—Chem. com.: 90·7 lead, 9·3 oxygen. Colour, red, streaked with yellow. Occurs in Yorkshire, Anglesea, and Siberia. Its variety is:

Plumbic Ochre.

SULPHATE OF LEAD.—ANGLESITE.—Chem. com.: 73·7 of protoxide of lead, 26·3 sulphuric acid, with a little silver. Colour, white, to yellow, grey, and brown. Occurs at most mines. Its variety is:

Cupreous Anglesite, containing an admixture of copper of an azure blue colour, and possessing a perfect cleavage.

CARBONATE OF LEAD.—CERUSSITE.—WHITE LEAD ORE.—Chem. com.: 83·6 protoxide of lead, and 16·4 carbonic acid. In colour ranging from white to black, fuses easily, and dissolves with effervescence in nitric acid. Its varieties are:

Dioxylite, *Leadhillhite*, and *Caledonite.* These are distinguished by the presence in larger proportions of carbonic acid.

PHOSPHATE OF LEAD.—PYROMORPHITE.—Chem. com.: 89·7 phosphate, and 10·3 chromate of lead, varied with 0 to 9 arseniate of lead, 0 to 11 phosphate of lime, and 0 to 1 fluoride of calcium. A brown variety gave the following composition: 78·58 of oxide of lead, 1·65 of muriatic acid, and 19·73 phosphoric acid. Usually of a greenish colour, and occurring in beautiful crystals. Its varieties are:

Hedyphane, containing some arsenic and 2 per cent. of chlorine. Found in Sweden.

Mimetine, containing also a proportion of arsenic. Cornwall.

CHROMATE OF LEAD.—CROCOISITE.—CHROME YELLOW.—Chem. com.: protoxide of lead, 68·15; chromic acid, 31·85. Colour, orange red to yellow. It has the following varieties:

Corneous lead, containing some carbonic acid, and occurring in white adamantine crystals. Derbyshire and Germany.

Melanochroite, containing only 23·64 of chromic acid, of a dark red colour. Siberia.

Mendipite, containing 38·4 of chloride of lead and 61·6 of oxide of lead. Mendip Hills.

Molybdate,—chem. com.: protoxide of lead, 64·42, molybdic acid, 34·25. Bleiberg.

Plumbo-resinite,—contains protoxide of lead, 40·14, alumina, 37·00, and water, 18·8.

Selenate of lead, containing selenium, rarely found; occurs in small globules.

Tungstate of lead,—chem. com.: lead, 49, and tungstic acid, 51.

Vanadinite, containing vanadium, and occurs in hexagonal prisms.

Omitting the mines of the Altai and Daouri mountains of Siberia, where lead ore is mined chiefly for the silver it contains, we will take as our easternmost starting-point, in our description of the chief lead ore deposits of the world, the mines of Austro-Hungary.

AUSTRO-HUNGARY.[1]—We have already seen that lead ores are associated with the minerals forming the contact deposits of the Banat, and these deposits will not require further description. The same remark applies to the lead associated with the silver ores mined on the Bohemian side of the Erzgebirge; but in the continuation southward of this mountain chain we find important mines worked at Przibam, and farther south still, near the village of Villach, near the NE. corner of the Tyrol, in the Carinthian Alps, are the lead mines of Bleiberg.

The deposits of Przibam lie between the upper surface of a greenstone rock and the overlying metamorphic schist, and thus form contact deposits. The matrix consists of quartz,

[1] See Whitney's *Metallic Wealth*; also *Ann. des Mines* (4) 8 and (4) 1.

brown spar, and heavy spar. The ore is galena, which is associated with antimony, blende, grey copper, iron pyrites, and silver ore. These deposits become profitably productive at a depth of about 300 feet. Besides the contact deposits, there are also true veins, which traverse sandstones and conglomerates of apparently the same age as those of our Shropshire and Cardiganshire lead mines. The number of veins of all sorts at this point is thirteen.

The mines that stretch along the valley of the Nötsch, between Bleiberg and Kreuth, a distance of about fifteen miles, occur in a light grey limestone, which is traversed by veins and cavities filled with calcspar, in which occur irregular masses of galena associated with carbonate of lead, calamine, and blende. These have been followed down to a depth of about 1,500 feet. The annual production of lead in Austro-Hungary is 7,000 tons.

GERMANY.—Passing by the mines of the Erzgebirge, which have already been described,[1] we find that near Tarnowitz, in Silesia, lead mining has been carried on for more than 300 years. A rich and curious deposit lies between the Muschelkalk and a dolomitic limestone. The deposit has been explored for a length of five miles and a breadth of one mile. It is about 12 feet thick, and consists chiefly of red calamine, with a bed two or three inches thick of galena in its upper portion. It is probable that the Muschelkalk lies unconformably upon the limestone: still the deposit is one of the highest known in the geological series. Crossing westward we reach about the centre of Northern Germany, and immediately south of the town of Hanover a network of mountains, made up of Cambrian and Silurian strata, that rises up out of the plains composed of the newer secondary deposits. These are the Hartz mountains, which send their spurs southward into the duchy of Nassau and down to Frankfort, while a succession of little, intervening, palæozoic islands show their connection with the mountain masses of the Erzgebirge already described.

The metalliferous portion of the Hartz mountains stretches WNW. by ESE. a length of sixty miles, with an average

[1] See page 86.

breadth of about eighteen miles. Its highest peak is the well-known Brocken, and it passes through the States of Hanover, Brunswick, and Anhalt Bernberg. The structure of the range is similar to that of the Erzgebirge, and if, referring to fig. 37, representing that mountain range, the reader imagines the central granitic mass to be the Brocken, he will have a fair idea of the structure of the country on either side that mountain, except that the strata are very much contorted, broken, and inverted. It is an old and important mining district.[1] The Rammelsberg mines have been worked uninterruptedly since the fifteenth century. The mines of Clausthal and Zellerfield were opened a century later.

In the Upper Hartz in Hanover there are two clusters or groups of veins, those of Andreasberg and Clausthal. Eastward there come the important mines of Rammelsberg, with mines of lesser importance farther east in Anhalt Bernberg.

At Andreasberg a space of about a mile and a quarter long by a mile broad is composed of clayey and sandy slates, which are traversed by a system of metal-bearing veins. The gangue or matrix of these is composed of fragments of the surrounding rocks, and contains brown spar, spathic iron, heavy spar, and quartz, the whole of which, with the lead ore, are cemented together by carbonate of lime. Besides the silver which is intimately mixed with the galena, the ordinary ores of silver, light and dark red ores, and antimonial sulphides also occur. One of the veins—the Great Samson—has been followed down to a depth of about 1,000 yards. The richest ores of this vein occur, usually, in courses of about 100 feet square. Some of the richest deposits, and those which have continued in depth, have been struck at a depth of about 360 yards.

The veins of the vicinity of Clausthal and Zellerfield are large and wide. There are six principal lines of fracture. These fractures course in nearly parallel lines from east to west, as do also the other veins of the region, generally speaking. The filling of the veins is similar to that of those of Andreas-

[1] See *Ann. des Mines* (4) x. xiii. xiv.; *Karsten and Dechen Archives*, x. 3.

berg. The lead ore is galena, which contains a good proportion of silver that varies from 12 to 120 ounces to the ton of ore. As a matter of observation the veins are richest where they are split up and divided, and poorest when widest and unbroken. The ramifications of the veins become at times so numerous as to form rich productive stockwerks, as at the Rosentiefe Zug.

The Rammelsberg deposit partakes more of the nature of segregated veins than of that of true lodes.

Fig. 79 represents a section of the principal orey deposit.

The deposit 1 lies between the bedding of the clay slates, A A. At a depth of about 400 feet the branch, 2, runs into the overlying slates. This mass of orey matter at its greatest thickness was 1,900 feet long and 150 feet thick. When followed down, from 1 to 3 in the figure, at a depth of 800 feet these dimensions had decreased to 750 feet in length and 20 feet in thickness. It may, therefore, be terminated in depth, or it may be connected by strings with a similar large deposit below. There is little admixture of gangue or earthy minerals in this mass, nearly the whole of it being made up of metallic minerals, chiefly sulphides of lead, copper, and zinc, all mixed up together.

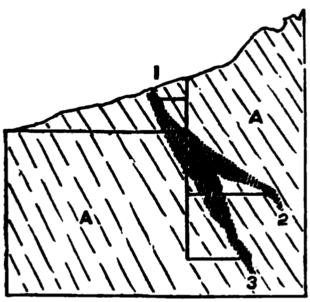


FIG. 79.—SECTION OF THE RAMMELSBERG DEPOSIT, HARTZ.

NASSAU.[1]—Following the continuation of similar strata to those of the Hartz, southwards, we find, where the older Devonian rocks cover them, the lead mines of the rich little duchy of Nassau. The group of mines extends from just above the confluence of the Lahn with the Rhine, passing by the towns of Ems and Nassau. The containing rock is supposed to be of Lower Devonian age—*Aeltere Rheinische Grauwacke*—and the lodes run NE. and SW., following generally the strike of the strata. It is just possible that, as at first interpreted, these strata

[1] See Odernheimer, *Berg und Huttenwesen im Nassau.*

may prove to be of Cambro-Silurian age. The veins have well-defined walls, but they are frequently disturbed by cross faults—north and south courses. The matrix is of a quartzy nature, and the lead ore is strongly charged with silver. It is also associated with blende, copper pyrites, and spathic iron ore. The veins are also crossed by fissures whose sides are lined with fine crystals. The veins also vary in productiveness as they traverse different strata in depth, being rich in hard and poor in soft beds of rock. In the year 1862 there were 18 lead and silver mines in this limited region in work, which produced 97,676 centners weight of lead and silver ore, to the value of 53,000*l.*

RHENISH GERMANY.—West of the Nassau lodes, in the region lying north of the Rhine, between Coblentz and Cologne, as well as in the hilly district between the latter town and that of Aix-la-Chapelle, along the western outcrop of the strata containing the Nassau lodes, lie the lead mines of Rhenish Germany. Near Olpe, in Westphalia, are eight principal E. and W. lodes, with many branches, the galena containing 80 ounces of silver to the ton. The total yield of lead in the old Prussian kingdom, in 1851, was 7,195 tons, and of silver 26,493 lbs. troy. The present total annual production of lead in the German Empire may be estimated at 50,000 tons.

SPAIN.—Before we proceed farther west, we had better take a run southward into this old lead-mining country. The mines of Spain were described by Pliny, and the Romans worked mines of lead, silver, and copper along the southern slopes of the Sierra Nevada. The mines flourished under the rule of the Moors, and declined after their expulsion. In these early workings the appliances were of a rude and ineffective kind, so that much lead was left in the slag after smelting, from which, of late years, it has been profitably extracted.

On the discovery of the rich mineral treasures of Spanish America, a rush was made from Spain to that country, so that the mineral resources of the old country were much neglected. Of necessity, the mines of mercury, near Almaden, were worked in order to furnish a supply for the reduction of the ores from

America. Mining, together with other branches of industry, languished during the Peninsular War; and it was not until after the issue of a royal decree by Ferdinand, which opened the mines of the country to all nations, that a revival took place. The effect of this revival may be judged from the facts that in 1826 more than 3,000 mines had been opened in the Sierras of Gado and Laja, and that in the year 1828 the total annual production of lead ore in the country had reached 42,000 tons.

The principal lead-producing districts have been—that of Gado, in Andalusia, just mentioned; the Sierra of Almagrera; the country between Carthagena and Almeria; and that of Linares, in the province of Jaen.

The deposits of Andalusia are not true veins, but large amygdaloidal-shaped masses of galena. They are contained in metamorphosed limestones of probably Cambro-Silurian age, answering very likely to the Llandeilo limestone of this country.

The mines of the Sierra de Almagrera are worked in micaceous slate, which is interstratified with beds of trap and porphyry, an horizon a little lower than that of Andalusia, and answering to the position of the Shropshire lead mines. These deposits occur in pockets and bunches along the line of bedding, and die out in depth, but would probably be renewed if they were followed downwards into congenial strata. In the upper portion of these deposits lead takes the form of sulphate, in which silver is most abundant, reaching a proportion of from 130 to 180 ounces to the ton. In depth the sulphate gives place to the sulphide of lead—galena, and the oxide of iron that prevails near the surface is replaced by the carbonate of that metal. Generally speaking, the ores of the Carthagena district are of poor quality, and are much mixed with blende and pyrites. Not lying deep they admit of being worked cheaply, and with modern methods of separating the silver at little cost from the lead, and improvements in the construction of furnaces, they may be worked to a profit.

Linares[1] is an important lead-mining district, and one that,

[1] *Notes on the Lead Mining District of Linares*, by Joseph Lee Thomas.

judging from the numerous excavations found there, was much worked by the ancients. The mining area is about 14 miles long from east to west, by 12 miles broad from north to south. The town of Linares lies on the south, and the northern boundary is the road leading from Madrid to Seville. The basement rock of this area, and lying in the south-west corner, is a compact granular felspathic rock, slightly micaceous. This is covered by a quartzose ferruginous sandstone, which in its turn is overlaid by a series of clayey slates, the whole being capped with a quartzose ferruginous sandstone, like that resting upon the granite. The strata dip to the north-east, and the whole series is traversed by granular felspathic dykes and veins.

The metalliferous veins traverse the whole series. There are about thirty of them, and they range—for the most part parallel to each other, between 40° and 70° east of magnetic north, with an underlie to the north-west, when they do deviate from the perpendicular. Their average width is about 3 feet, but they contract down to one, and open out into lodes 12 feet wide. The earthy filling of the most productive lodes is the decomposed granular felspar, traversed by veins of quartz, and containing in places much sulphate of baryta. At a depth of from forty to fifty fathoms, carbonate of lime and calcareous spar prevail, and are arranged in parallel layers on the walls of the lodes. Of metallic minerals, carbonates of lead, copper pyrites, and the carbonates and oxides of copper prevail near the surface, but in depth these give place to galena. When rich bunches of ore occur in the hard granular rock, they soon cut out, the ore being most plentiful in soft granular rock, where the felspar is large grained, white in colour, and easily decomposed. In the clay slates the ore is more plentiful in those of a light blue colour of a moderate consistency, than in those of a sandy or flinty character. The ore is more persistent in the perpendicular lodes, and becomes bunchy and irregular as they incline to a horizontal direction. Sulphate of lead is more common in the sandstone capping, and arsenical pyrites prevail more in the slates than in the granular rock.

The lodes have been followed downwards for over 200

yards; some of them are worked by English companies, one of which, the Linares, has returned to the shareholders 17*l.* 3*s.* 10*d.* for each 3*l.* share subscribed, and the Alamillos has returned 1*l.* 18*s.* 3*d.* on each 2*l.* share.

Numerous old lead mines are found near Hornachos, in the province of Badajoz, in Western Spain. Some of these have been taken by an English company, but as yet they have not reached a successful issue. Samples of lead from these mines of ordinary percentage have assayed 80 to 100 ounces of silver to the ton of ore. In the year 1878 we imported into this country from Spain and Portugal 78,380 tons of pig and sheet lead, and 1881 tons of ore. Taken with the home consumption, therefore, the total annual production of lead ore in these countries may be estimated at 130,000 tons.

ALGERIA.—The silver lead mines of Kefoun Teboul, near La Calle, raised 12,173 tons of ore in the year ending July 31, 1877.

FRANCE.[1]—The lead mining districts of France may be classified thus: Those of Savoy and the High Alps; the east of France; the south-east, comprising the Low and Maritime Alps, and the Pyrenees; the Central Mountains; and the west of France. The geological position of the mines in the High Alps is similar to that of Isère, described already in the chapters on silver.

The principal lead mines of the country are probably those of Pontgibaud, in the Puy-de-Dôme, in Central France. The veins here have a NE. and SW. tendency, and they traverse slates, passing downwards into gneiss and granite. The matrix of the lodes contains a good deal of felspar with courses of sulphate of baryta, especially near the surface. The metallic ores occur in pillars or columns holding, usually, in depth, but separated from each other horizontally.

The mines of Poullaouen and Huelgoat in Vendee were formerly of much importance. There are three principal veins running 22° west of north. One of these has been traced for over a mile in length, and they have all been worked to a depth

[1] *Mines Métalliques de la France*, M. Alfred Caillaux.

of about 350 yards. They are filled with argillaceous rock like that of the country, through which are threaded veins of quartz. The metallic minerals are silver galena with silver and blende. The veins traverse slaty rocks, interstratified with quartzites and porphyries.

Many remains of old silver-lead mines are found in Bretagne.

M. Cailloux estimates the total production of lead from mines spread over the districts enumerated at 14,741 tons a year.

Belgium.—Lead is mined to a small extent in Belgium. At La Nouvelle Montagne, near Verviers, the ore occurs in pear-shaped masses and cavities, which range over and on a line with fissures in the Carboniferous limestone. The galena is mixed with blende, which, together with calamine, forms the most important ore at the mine; the deposits will be more fully described in the chapters on zinc ores. About 10,000 tons of lead ore, on the average, are raised annually in Belgium; the production for 1876, however, reaching as high as 12,422 tons.

NORWAY.—In Susendalen, North Norway, lead ore containing 150 ounces of silver to the ton occurs in clusters of thin veins that traverse a pale-coloured limestone of probably Cambro-Silurian age from NW. to SE.

In the south of the country, on the west side of Christiana Fiord, a great mass of granular felspathic rock is impregnated with lead ore to the proportion of 20 per cent. of the mass, and the ore contains 50 ounces of silver to the ton. In the same neighbourhood lead ore rich in silver occurs in true lodes that traverse chloritic slaty rocks from NW. to SE.

Of the other countries of Europe the island of Sardinia produces lead annually to the extent of about 23,000 tons, and Greece 8,000 tons.

In the latter country the lead is said to be derived chiefly by the resmelting of old slags, and to contain from 16 to 20 ozs. of silver to the ton.

CHAPTER XXIV.

LEAD—continued.

Lead Mines of the British Isles—Statistics—Lead Mines of Shropshire—Montgomeryshire—The Van—Cardiganshire—Brief History of the Lead Mines of Cardiganshire, and Modes of Occurrence of the Ores.

THE total annual production of lead ore in Great Britain and Ireland, for the three years ending December 1877, was 79,231 tons. The production for 1877 reached 80,850 tons. In 1879 it was only 66,840 tons. The rocks and strata whence this great quantity of ore was derived belong to three distinct zones, which are, beginning with the lowest: first, the Cambro-Silurian strata of Shropshire, Cornwall, Wales, Scotland, Ireland, and the Isle of Man; secondly, the Devonian strata of Devonshire, and possibly of part of Cornwall; and, thirdly, the Carboniferous limestone of the Pennine chain and of North Wales. I will begin my description of the British lead ore deposits by describing those of the Cambro-Silurian strata of Shropshire and North Wales.

Shropshire.[1]—The lead mining district of this county lies in its south-west corner, bordering on Montgomeryshire. It is small in extent, forming a strip of ground about four miles wide, lying between the range of the Stiper Stone hills on the SE., and the road from Minsterley to Bishop's Castle on the NW., and extending from the former place on the NE. about seven miles towards the latter on the SW.

It is a district of considerable historical importance—the Roman Gravels Lead Mine, at present one of the most pro-

[1] See also Morton, 'Mineral Veins of Shelve,' *Proceedings of Liverpool Geological Society*, 1868–9; also 'Roman Mining Operations on the Borders of Wales,' T. Wright, *Intellectual Observer*, vol. i. 1862.

ductive mines of the district, deriving its name from the old surface workings left by the Romans. These old workings now appear as open trenches, rounded by time, that extend along the hillside following the course of the veins. In some places these trenches are now 20 feet deep. Roman mining tools are occasionally found, and a Roman pig of lead was obtained from the bottom of the Roman vein. Another was found at Snailbeach, the chief mine of the district, and another at Snead. All of these bore the mark of the Emperor Hadrian. Those from Snailbeach and Snead are in the museum at Liverpool. The mines seem also to have been worked in the twelfth and thirteenth centuries. The slag left by these old workers still contains a quantity of lead.

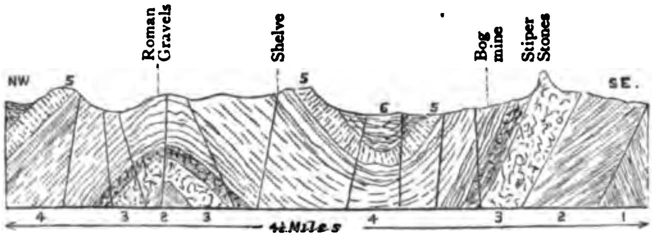


FIG. 80.—SECTION OF STRATA IN THE SHELVE MINING DISTRICT, SHROPSHIRE.

1, Lower Cambrian rocks of the Longmynd. 2 2, Upper Cambrian rocks, probably Lingula flags and Tremadoc beds. 3 3 3, Stiper Stone rock, rough bedded, and partly intrusive, and probably answering to the Corndon base of the Arenig group. 4 4, Arenig and Llandeilo beds. Lead-bearing strata, with interstratified and intrusive porphyries, greenstones, and ash beds. 5 5 5, Bala beds. 6, Small patch of Llandovery.

The geological structure of the district is illustrated by the general section given in fig. 80, which stretches across the SW. portion of the mining area. The strata described in the section are the easterly continuation of the great Cambrian and Cambro-Silurian groups of rocks in North Wales—the Stiper Stones probably answering to the Greenstone that lies at the base of the Arenig strata. The whole of the strata are traversed by veins that have a general direction from WNW. to ESE. There are, however, others which have an opposite course, but the direction given is that of the most productive lodes. For the most part the veins are simple fissures in the strata, some

lying, but probably not to any great extent, along lines of dislocation.

The mineral contents of the veins vary as the latter traverse strata of different ages. In the Cambrian rocks of the Longmynd, on the SE. of the section, and the strata lying up to the Stiper Stones, they contain copper. In portions of the Arenig and Llandeilo beds, the deposits of lead are found, and in the overlying Bala group they are almost solely charged with baryta, which is largely worked in the district. As we pass into the counties of Montgomery and Cardigan we shall see that the lead mines range along the anticlinals, where, as shown in the section, at the point where the Roman Gravels Mine is situated, the Llandeilo beds are thrown up to or near the surface.

The lead-bearing strata, 4 4, are about 5,000 feet thick. They consist of dark slaty beds, sandstones, and shales, which are traversed by greenstone and felspathic dykes, and contain interstratified trap and porphyritic rocks. The veins are most productive of ore in the hardish slates; they are pinched in very hard strata, and become unproductive when they enter soft shale. There are three principal interstratifications of shale, which thus divide the runs of ore into four portions or floors, as they are locally called.

The veins are chiefly filled with fragments of the rocks through which they pass, cemented together with sulphate of baryta, carbonate of lime, and quartz. The lodes at the Snailbeach Mine present some massive groups of crystals of the latter, with galena and blende grouped about the base. Fluorspar is also found in the lodes of this mine in sufficient quantity for sale. In most of the lodes, the galena and blende lie in irregular strings, which now and then open out into nests of ore. In their rich portions, some of the veins now yield 3 tons of lead ore to the fathom, but most of them, for long distances, do not average more than 15 cwt.

The richer orey portions of the lodes occur as columns, runs, or pipes of ore, and fig. 81, adapted from Moissenet,[1]

[1] *Ann. des Mines* (6), 9, p. 10.

represents a longitudinal section of a lode at Snailbeach, and shows the relative width of these to the unproductive ground. In this case, however, the courses of ore correspond to the floors in mines where the strata lie more horizontally. These courses are really 'floors' tilted up at a high angle, the dip of the shoots corresponding to the angle made by the intersection of the lode dipping 62° from the horizon southward, and the dip of the strata 50° from the horizon to the south-west. These shoots of ore have in this mine been followed downwards to a depth of 500 yards.

In 1876 there were eleven lead mines in this district. Of these, seven made returns of lead ore amounting to 7,713 tons,

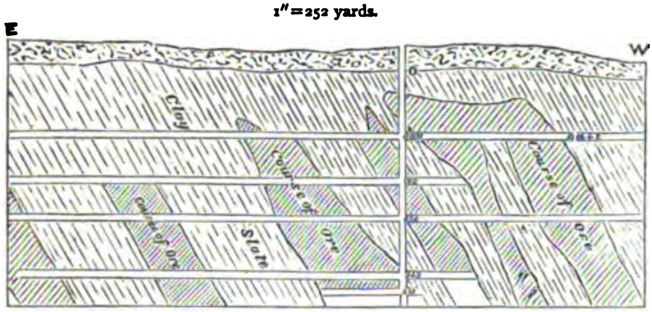


FIG. 81.—SECTION OF STRATA, WITH COURSES OF ORE ALONG THE RUN OF A LODE AT SNAILBEACH MINE, SHROPSHIRE.

which yielded 5,955 tons of lead. Two of the mines only, Tankerville and West Tankerville, gave proportions of silver, which in their case amounted to 2,748 ounces from 1,830 tons of ore.

Montgomeryshire.—In the north-west corner of this county there is a small lead-producing district immediately surrounding the village of Llangynog. The 'Old Mine,' commercially known as the New Llangynog Mine, has been in work about 150 years, and in 1876 it yielded 176 tons of ore, with 400 ounces of silver. Besides this mine, there is the Craig y Mwyn, an old mine now called Llanrhaiadr, another called Cwm Orog, and several other trials, and for the present abandoned mines.

These mines are all worked in the Arenig and Llandeilo beds of the Cambro-Silurian strata. Fig. 82 is an illustration of the order and position of these beds at this point, and I give it for the purpose of assisting us to understand the structure of the Van district, some thirty miles to SW., along the strike of these beds. The earthy minerals of the Llangynog lodes consist largely of the carbonates and sulphates of baryta, with carbonate of lime, and some quartz. The lodes vary greatly in thickness. I have measured the one formerly worked at Cwm Orog, 12 feet wide, where immediately below it has dwindled down to a thread. At all the mines the lodes have been most productive in the hard rocks, especially in the porphyritic rock, where, occasionally, there has been two feet of solid ore. When the lode passes into slate rock it is not so

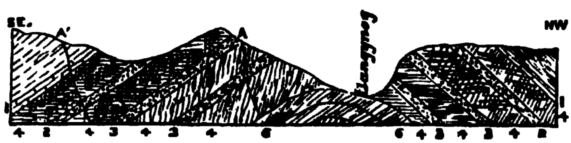


FIG. 82.—SECTION OF STRATA AT LLANGYNOG, NORTH WALES.

1, Bala Limestone. 2 2, Bala ash. 3 3. Interstratified trap rocks. 4 4 4, Slate ro ks (Llandeilo beds). 6 6, Arenig beds. A, Lode at New Llangynog. A' Lode at Bwlch Creolas (unproductive).

productive, and when into shale it is impoverished. In the old Rhiwarth mine a good deal of blende and some sulphide of copper are associated with the lead ore which also contains a good proportion of silver, and occurs chiefly in ribs and strings on the heading side of the lodes. As in Shropshire, the lodes are barren when they pass upwards into the Bala beds, and of this the Bwlch Creolas lode on the SE. of the section is an example.

In their progress southward toward Llanidloes we find the porphyries and greenstones of the Arenig and Llanidloes beds losing their massive and partially igneous character, but it is in the solid massive slaty beds, that there take their place, that the lodes are, as we shall see, most productive of ore.

As late as the beginning of the present century the Rev.

Walter Davies, in his 'Report on North Wales,' expressed the opinion that the Plynlimmon or Severn range of hills in all probability contained but few ores of metals, and that it seemed to be the most unpromising of all ranges for mine adventurers. Recent mining operations have shown that, shrewd observer as he was, in relation to a portion of the range he was mistaken in this opinion.

The veins of the Llanidloes district have a general east and west direction, with a dip to the north. The principal lode is now known as the Van, and operations have been made on this lode during the present century. At least six mines have been started, renewed, and abandoned. The Van property was leased from Earl Vane in the year 1850. After two years' unsuccessful search for the lode in a profitable condition it was abandoned. Working was recommenced after two years' idleness, when Captain Williams, of a neighbouring mine, discovered a richer portion of the lode by costeaning. Another three years' operations brought no satisfactory result, and the mine was again near abandonment. Two men were, however, kept at work, and in 1862 a winze that was being sunk cut the lode where it showed good spots of ore. This discovery led to the driving of a cross-cut, which, at a distance of 150 yards from day, cut the lode in a productive state, at a depth of 60 yards from the surface. In April of the next year the first parcel of ore of 40 tons was sold, and from that date the mine has been one of the most successful in the kingdom. Its production of lead ore in 1876 was 6,850 tons, which also gave 5,136 ounces of silver.

Fig. 83 is a cross section of the lode, and of the way in which it is approached, as well as of the strata it traverses. It is a monster lode, varying in width from 12 feet to 80 feet. It is largely filled with the redeposited material of the surrounding rock, which is traversed by veins of calcareous spar, quartz, and baryta. The ore is sometimes distributed throughout the whole mass in small bunches connected by strings, and sometimes it is most abundant near to one or other walls of the lode, chiefly the lower or heading side; but it is seldom present in

force on both sides at the same time. It will be seen by a

1" = 22 fathoms.

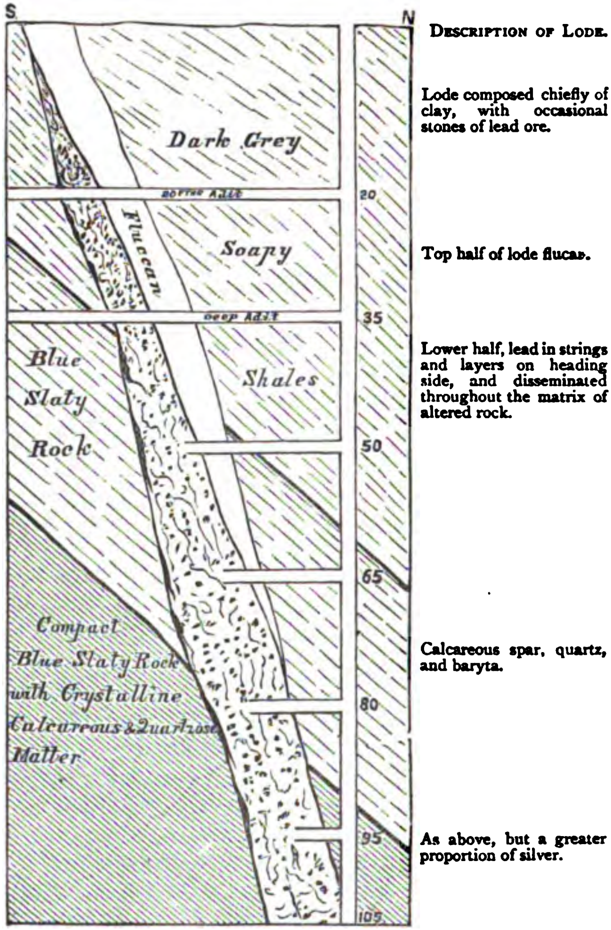


Fig. 83.—Section of the Van Lode, Montgomeryshire.

reference to the section, fig. 83, that for 20 fathoms from the

surface the lode traverses dark soapy shale, and it is not very productive, the lode being filled with clay and occasional stones of ore. From this point down to 75 fathoms, as the lode traverses blue slaty rock, the upper part of the lode is also filled with clay (flucan), and the lower part is more solid and contains ore. The flucan thins out like a wedge and dies away, leaving a solid lode. From 75 to 105 fathoms the lode traverses a blue compact slaty rock, a little calcareous in places, and arenaceous in the lower part. Here the lode contains crystals of calcareous spar and quartz, and in this portion of it the lead ore contains most silver. Taking it all through it is not a very rich lode, but there is plenty of it to cut at, and the appliances above ground are very efficient.

Another great mine, the Dylefe, lies westward, on the borders of Cardiganshire. Its output in 1876 was 1,000 tons of lead ore.

In 1876 there were 37 lead mines in this county, of which 13 only made returns of ore, amounting in the aggregate to 9,041 tons.

Cardiganshire.—Journeying westward we reach the old and important lead mining district of Cardiganshire.[1]

The discovery of oval-shaped dressing stones in the old open workings at Cwmystwith Mine point to a high antiquity, and it is probable that some of the mines were worked by the Ancient Britons. It seems pretty certain that they were worked by the Romans. We do not, however, know anything definitely about them until the reign of Queen Elizabeth, who procured from Germany two miners, named Thurland and Hochsetter, to whom she gave great privileges. Subsequently these were extended to the 'Society of Mines Royal,' who ultimately sublet the mines opened and worked by them to Sir Hugh Myddelton, who worked them with great vigour and success. He accumulated a large fortune, but, like many other men of an engineering turn of mind, he spent it all in the

[1] See 'Notices of the History of the Lead Mines of Cardiganshire,' by Robert Hunt, *Memoirs of the Geological Survey of Great Britain*, vol. ii. part 2; also 'The Mining District of Cardiganshire,' by Warington W. Smyth, in the same volume.

prosecution of another enterprise, which, in his case, was the bringing of the New River to London. The presence of a large proportion of silver led to the establishment of a mint at the silver mills in the district. A Mr. Bushell next took the mines, and spent the proceeds in the defence of Charles I. The Esgair Hir and adjacent mines, now known as the Cambrian, were discovered in 1690. For the working of these mines a 'Mine Adventure' was established in 1698 with a capital of 20,000*l.* A noticeable feature of this scheme was that one-twelfth of the profits were to be devoted to charitable uses, especially for the building of schools in Wales; but it does not seem that much money could ever be spared for these purposes. This mine adventure attracted much attention between the years 1710–20, and it appears that the promoters got themselves into difficulty with their 650 shareholders. We next find some adventurers from Flintshire working the Darren Mine with some others, and then little is known of the Cardiganshire mines until an account of the state of mining in the county in the year 1810, with a list of 30 mines, was published by Sir Samuel Rush Meyrick.

The Cardiganshire lead district extends from the SW. boundary of Montgomeryshire, where it joins the mineral district of that county, south-westward to the sea in Cardigan Bay. It consists of several roughly parallel mineral zones, running in the same direction, and which correspond to the strike of the Llandeilo strata, as these come in anticlinal curves to the surface in the manner shown and explained in the Shropshire section, fig. 80, at the Roman Gravels Mine: the barren belts of ground between these zones being for the most part troughs or synclinal curves, filled with Bala, Llandovery, and Wenlock strata. These zones may be briefly described thus, beginning on the north-west and coming back eastward: the first belt consists of the range of hills that skirt the south side of the estuary of the Dovey, in which are the mines of Taliesin, Tre'rddol, Bryn yr Arian, Talybont, and others. The bulk of the galena of this zone does not contain much silver. It has a little blende, and some copper pyrites.

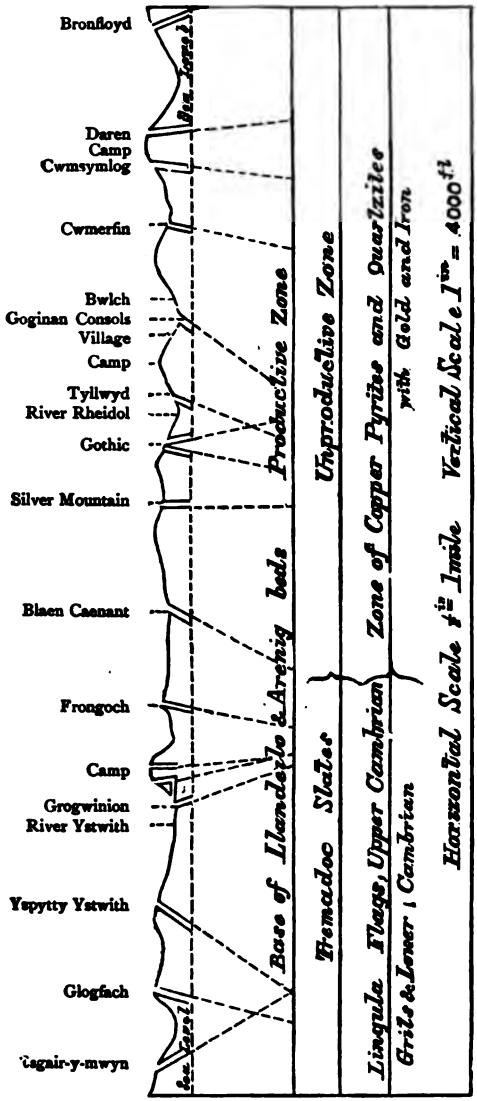


FIG. 84.—SECTION IN CARDIGANSHIRE, SHOWING PROBABLE THICKNESSES OF THE MINERAL ZONES.

The second belt runs at some little distance along the SE. side of the first, and is the one of most historic wealth and importance, being associated with the labours of Sir Hugh Middleton. It contains a long series of mines, in some of which the proportion of silver reaches 40 ounces to the ton. Fig. 84 illustrates the position of the mines along this belt, and I shall have to refer to it presently in relation to productive depths.

The third zone runs from the Devil's Bridge along the course of the Rheidol. It contains the Llewernog, Powell, Consols, and other mines. For the most part the lodes here occur in a grey argillaceous rock, and become poor in soft fissile, dark slate. The lodes vary much in character, some being distinguished for silver, others for blende, and others for iron pyrites; manganese is also sometimes present.

The fourth zone runs from the centre of Plynlimon down to Lampeter. It contains the mines of Esgair y Mwyn and Loganlâs. Some of the lodes contain calcareous spar and zinc ores. To the SE. is the silver lead lode of Llanfair Clydogan. The higher rocks partly cover this belt.

The fifth belt ranges from the east side of Plynlimmon. In its extension NE. into Montgomeryshire are the mines of Llanbrynmair and Dylefe. In the southern part of the belt the slaty rocks have frequent interstratifications of sandy matter. The lodes of this belt contain an appreciable quantity of copper pyrites.

The lodes range from ENE. to WSW., but this direction is so varied by cross courses and other causes as to assume, especially in the smaller lodes, a zigzag shape. Most of the productive lodes are within a few degrees of this direction. Among the few exceptions are the NW. and SE. lode of the old Taliesin Mine, the WNW. Comet lode of Cwmystwith together with a few that have a true meridional direction. The lodes, with few exceptions, dip to the north.

The amount of inclination or dip is very great—60 to 80 degrees from the horizon. The Comet lode at Cwmystwith is

flatter, 30 to 40 degrees, and it is observable that in this case the lode does not deteriorate, as it assumes a flatter dip, the strata probably being favourable.

The gangue of the lodes consists primarily of quartz of different varieties, with which are intermixed fragments of the adjacent slate rock. Next to quartz, calcareous spar prevails in the lodes—a remarkable lode, consisting chiefly of carbonate of lime, occurring in the bed of the river Ystwith at Pontrhyd-y-Groes. It occurs also in large ribs at Hênfwlch and Esgair Hir, where ores of copper and zinc occur with those of lead.

There are the usual disturbances of the lodes by horses, cross courses, ramifications, and the like, and the principal lodes are often accompanied by riders and small adjacent lodes, which are of a subsequent age.

Galena is the most abundant lead ore in the lodes. It occurs occasionally in solid ribs and masses of pure ore, but oftener in network and strings, and intimately mixed up with the non-metallic contents of the lodes.

Lead ore is most abundant where the quartz of the lode is of a cellular, drusy, and friable nature, and is usually poor when the quartz is massive and solid, and also when there is an absence of quartz and calcareous spar from the lode. When calcareous matter abounds, copper ore, as carbonate, is often found. Iron pyrites is also abundant in such conditions, as in some of the Ystumtyn lodes. Copper pyrites is also irregularly sprinkled with galena, especially near the surface, but it is seldom found in quantities sufficient to pay for extraction. A good mass of it in a pure state was found some years ago in the old Tre'rddol Mine, and several parcels of 50 tons or so have recently been sold from Esgair Ffraith Mine, but there is no example in the district of copper having been persistently profitably worked.

Both carbonate and phosphate of lead are occasionally found, the former near the surface, the result probably of the percolation of water charged with carbonic acid. The latter occurs as minute crystals, which are the result of the contact of the galena with organic matter in a state of decomposition.

The most abundant metallic associate of the galena is black jack or blende. Calamine is also found, but not in merchantable quantities.

Lead ore is most abundant where the lodes traverse compact, thick-bedded, slaty rock of a bluish or greenish grey colour and a soapy feel. They become impoverished when this is exchanged for soft shaly strata or gritty sandy beds. In the softer strata the lodes become indistinct and disordered. This fact formerly led to the supposition that the lodes of the district did not bear in depth. Gradually, however, these softer beds have been pierced, and harder strata, in which the lodes again became productive, have been found below.

The lodes consisting chiefly of re-formed country rock without much carbonate of lime, are poor in lead ores. They are too 'countryfied,' as the miners say. The presence of carbonate of lime in moderate quantities as sugary spar is favourable for the production of ore.

The ore bodies have a general dip towards the west, and where the strata are favourable they are more continuous vertically than horizontally.

In the year 1877 there were 69 lead mines in Cardiganshire, of which 31 made returns of ore, amounting in the aggregate to 5,850 tons, from which were derived 47,284 ounces of silver, or about an average of 8 ounces to the ton. The mines most productive of silver were, Great Darren 26 ounces, and Goginan and Level Newydd 22 ounces to the ton. As I write I hear that Court Grange has just sold a parcel of ore, the assay of which gives 34 ounces of silver to the ton.

In the year 1878 the mines were 52 in number, of which 32 made returns of ore amounting to 6,801 tons, with 49,028 ounces of silver.

CHAPTER XXV.

LEAD—continued.

Lead Mines of Carnarvonshire, of the Isle of Man, of Cornwall—West Chiverton—of Devon, of the North of England—Northumberland, Durham, Westmoreland, and Cumberland—of Yorkshire, of Derbyshire—Lead Mines of the Limestones of Flintshire and Denbighshire—Lead Mines of Ireland.

Carnarvonshire.—An interesting lead mining district is situated in this county. It forms a triangle, a line stretched from Trefrhiw to Capel Curig forming its base, and the picturesque village of Bettws-y-Coed forming the apex. It is a district

Vertical Scale 1″ = 50 yards.

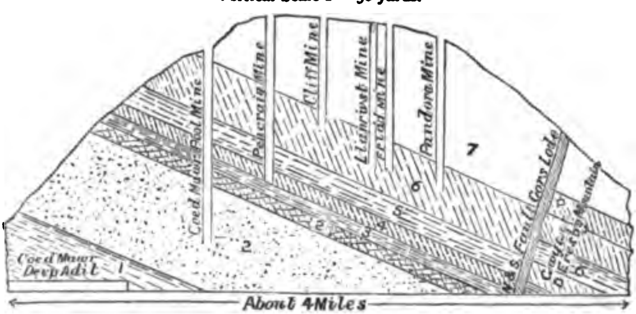


FIG. 85.—SECTION OF THE LLANRWST MINING DISTRICT, SHOWING THE COMPARATIVE DEPTHS OF SEVERAL MINES, AND THEIR RELATION TO THE STRATA.

1, Blue slaty rock. 2, Grey gritty rock, the most productive of lead ore. 3, Yellowish felspathic rock, ore good, but lodes pinched. 4, Dark slate, ore fairly rich. 5, Hard blue slaty rock, with fine quartz veins; not much ore. 6, Black slate, not productive. 7, Alternations of slaty rock, as 4 and 5, with hard felspathic beds, lodes pinched in the latter.

which has, like many others, formed the victim of mining gambling: sums of money having been paid for mines which could not possibly pay a reasonable interest in return, but which

nevertheless, if worked economically, would form moderately profitable undertakings.

Fig. 85 is a general section of the strata from Capel Curig to Llanrwst, and it will illustrate the geological position of the mine.

The depths attained by the various mines are not great; the approximate depths being: Coed Mawr, 56 yards; Bettws-y-Coed, or Pencraig, 60 yards; Cliff, 45 yards; Llanrwst, 60 yards; Willoughby, or Pandora, 60 yards; and Clementina, 100 yards. The most productive rock is a compact greenish grey rock with white spots, and it will be seen that the eastern mines, although some of them are the deepest of the district, have not yet reached this rock.

The lodes have an east and west direction, and dip south about two feet in a fathom. They are from two to four feet wide, and contain quartz and calcareous spar, the latter being most plentiful in the higher strata. The ore occurs in vertical pipes or courses, and it is noticed that these lie opposite each other in the different lodes, probably in the run or strike of the same strata. The ore occurs in parallel layers, as shown in fig. 86, which is a section of a small lode in the old Pencraig Mine. Beautiful examples of this banded and comby structure may be seen on the ore heaps at the mines.

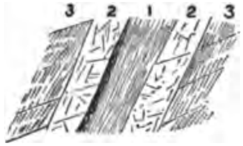


FIG. 86.—SECTION OF LODE IN OLD PENCRAIG MINE, CARNARVONSHIRE.

1, Solid lead, three inches wide. 2 2, Quartz, with strings and lumps of lead ore, crystallised on the hanging side. 3 3, Slaty rocks.

On the north-east side of the district there is a large north and south lode, which probably lies on a line of dislocation. It is known as the Gors lode. It is from 12 to 30 feet wide, and is represented as containing about 4 tons of lead to a fathom high and forward of its whole width. It is now being opened on in the D'Eresby Mountain Mine, and probably before this edition passes through the press we shall know whether it may be worked to profit. The strata are of Cambro-Silurian age, and in the same strata in the Point of Lleyn, near Pwllheli, are some of the most productive mines of the county. In 1878 there were 40 lead mines in Carnarvonshire, of which 12 yielded 2,144 tons of lead ore, with 4,392 ounces of silver.

Isle of Man.—This island has eleven lead mines worked in strata similar to those just described. Its production of ore in 1876 was 4,353 tons. Two of the mines produced the greater part of this amount: Great Laxey 2,500 tons, and Foxdale 1,607 tons. The ore is exceedingly rich in silver, reaching as it does a proportion of 40 ounces to the ton of ore.

In 1878 the production from nine mines was 3,920 tons of ore, with 397,471 ounces of silver.

Lead mines similarly situated are worked at Lead Hills in Scotland, in Ireland, in Cumberland, and in several of the

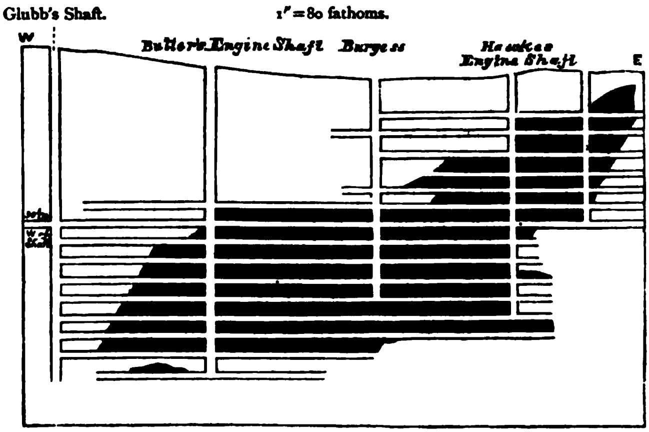


FIG. 87.—SECTION OF THE WEST CHIVERTON LEAD MINE.

Welsh counties besides those already named, but they do not call for special remark. I must, however, devote a few words to the mines of Cornwall and Devon, before I pass on to notice the lead mines worked in the Carboniferous Limestone.

Cornwall.—In 1876 this county had 16 lead mines, producing 2,727 tons of ore. Of this quantity West Chiverton, near Perranzabulo, gave 1,594 tons. Old Treburget, near Camelford, 444 tons, and Herodsfoot, near Lanreath, 296 tons, leaving the remaining 393 tons to be contributed by the remaining 13 mines. The whole of the lead mines occur in the eastern half of the county. The proportion of silver produced is large, about 13 ounces to the ton. The mine most

productive of silver was the West Chiverton, of which a section is given in fig. 87. Its yield of silver in the quantity of lead ore named was 29,925 ounces.

The lode at this mine has a general east and west direction, with an inclination or dip of two feet in a fathom to the south. It averages six feet in width, and is filled chiefly with quartz clay (flucan) and carbonate of lime. The galena occurs principally in layers, although in places it is disseminated generally throughout the lode. An elvan dyke crosses the vein at about 20 fathoms from the surface, dipping south more rapidly than the lode itself. As a matter of experience it is found that in the neighbourhood of these dykes the ore is usually more abundant and richer in silver.

The mine is 160 fathoms deep, and at the 90 fathom level, a junction was formed between two branches and the main lode, and the result was extraordinary mineral riches. The lode was worth 100*l.* per cubic fathom for lead, and 30*l.* for blende. The vein here was about nine yards wide, and presented a series of ribs of lead and blende, twelve to sixteen inches in width, with ribs of quartz between. The strata traversed is only described as clay slate, and with the classing of all strata, besides granitic rocks in Cornwall as Devonian, we are left in uncertainty as to its age. One thing is, however, certain, the lead strata lie above the tin and copper-bearing rocks, and hence at a greater distance from the central bosses of granite. We are only left in doubt as to whether the strata, like all those I have hitherto described, belong to the Cambro-Silurian, or, as shown on geological maps, to the lower part of the Devonian. In the absence of fossils to decide the matter, the strong probability is that they belong to the lower group. It will be observed from the section of the mine, fig. 87, that the course of ore has a defined width, and a westerly downward direction, which may coincide with the thickness and dip of productive strata.

The lode at Herodsfoot Mine approaches more nearly a north and south direction, its exact bearing being N. 8° to 12° W. It dips from 70° to 80° east; it varies in width from a few inches to four feet; has on one side, usually the heading, a

brecciated quartzy capel, and cavities containing crystals of quartz. Fig. 88, as given by Dr. Le Neve Foster[1] from a part of this lode, will illustrate its structure. The lode seems to be the nearest approach to a profitable north and south lode we have, although, as already observed, this also has a bearing towards east and west. The strata traversed by this lode are dark blue, green, and drab coloured slates, which are interstratified with felspathic rocks which sometimes pass into a slaty structure. In the neighbourhood of the mines fossils have been found indicative of a Lower Devonian age; but as we have no depths or distances given for the horizon of these fossils, and as the lode itself seems to be a line of dislocation, we are still a little uncertain as to the age of the true lead-bearing strata.

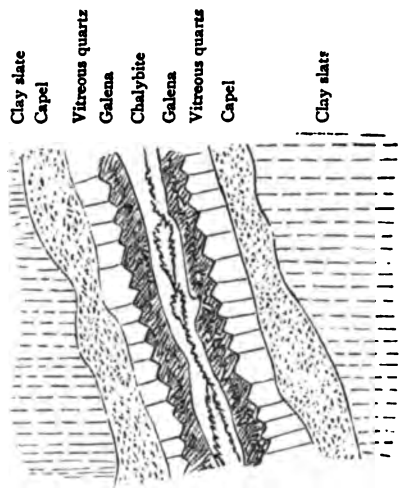


Fig. 88.—Section of Lode in Wheal Mary Ann Mine, Cornwall.

These two mines, producing as they do the great bulk of the lead raised in the county, will suffice as illustrations of the Cornish lead lodes.

In 1878 thirteen mines yielded 1,349 tons of lead ore, with 16,456 ounces of silver.

Devon.[2]—Although historically a lead-mining county of importance, Devon numbered in 1876 only ten lead mines, and of these three only made returns of ore, amounting alto-

[1] On 'The Lode at Wheal Mary Ann,' *Trans. Royal Geological Society of Cornwall*, vol. ix. part 1, 1875.

[2] See also De la Bêche, *Geological Report on Cornwall and Devon;* also G. Chowen, *Some Account of the Rise and Progress of Mining in Devonshire.*

gether to 437 tons with 5,890 ounces of silver, or about 13½ ounces to the ton. The two principal mining districts are Beer Alston on the banks of the Tamar in the south, and Combmartin in the north of the county. Reference is made to mines in these districts in the thirteenth century, and the argentiferous nature of the lead ore was then well understood. The geological position of the lead-bearing strata will be understood from the following table of the order of the Devonian strata:

Upper Devonian Beds	1. Pilton Slates.—Copper ore in places with galena and blende.
	2. Cucculæa Sandstone.
	3. Pickwell Sandstone.—Veins of hæmatite with oxide of manganese.
Middle Devonian	4. Northoe Slates.—Quartz veins, but little or no metallic minerals.
	5. Ilfracombe Slates and Limestones.—Horizon of the silver lead mines of Combmartin and elsewhere, copper, blende, and some antimony.
	6. Martinho Beds.—Containing beds of iron along the strike of the beds.
Lower Devonian	7. Lynton Beds.—No metals.
	8. Foreland Sandstones.—Iron ores.

At Combmartin Mine the lode traverses a bed of clay slate near its junction with limestone rock; the galena, which often occurs in courses and masses on the lower side of the lode, is associated with flucan, quartz, and white iron. In the lodes of Beer Alston, which traverse calcareous slates, the matrix consists of fluorspar, and the lead ore is disseminated through the lode in small lumps.

We now approach the consideration of the important and extensive deposits of lead ore contained in the Carboniferous Limestone of England and Wales, beginning with those of the north.

Northumberland, Durham, and Cumberland.[1]—Lying on the military road known as the Maiden Way, the mining dis-

[1] See also Westgarth Forster on *Strata in the North of England;* Sopwith, *Geological Sections of Lead Mines in Alston Moor and Teesdale;* Wallace, on *Lead Ore in Veins on Alston Moor; The Industrial Resources of the Tyne, Wear, and Tees,* by Armstrong and others.

trict formed by the junction of the three northern counties just named became known to the Romans—traces of whose ancient smelting houses still exist. Not much, however, is heard of these northern mines until 1468, when Edward IV. granted to the Earl of Northumberland, with others, all mines north of the Trent. Seventy years later were granted to the Earl of Northumberland and the Duke of Gloucester all the mines of Blanchland, the mines of Alston Moor, with others in the north. Several of the mines subsequently passed into the hands of the Governors of Greenwich Hospital, to whose successors they still belong. The royalties of Allendale passed through several owners into the family of the present owner, W. B. Beaumont, M.P. The Weardale mines belong to the Ecclesiastical Commissioners.

The advent of Smeaton into the district in 1775 led to a

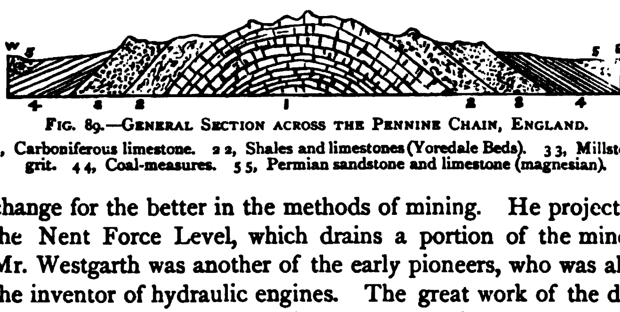


FIG. 89.—GENERAL SECTION ACROSS THE PENNINE CHAIN, ENGLAND.
1, Carboniferous limestone. 2 2, Shales and limestones (Yoredale Beds). 3 3, Millstone grit. 4 4, Coal-measures. 5 5, Permian sandstone and limestone (magnesian).

change for the better in the methods of mining. He projected the Nent Force Level, which drains a portion of the mines. Mr. Westgarth was another of the early pioneers, who was also the inventor of hydraulic engines. The great work of the district is the Blacket Level, which was begun in 1855, near Allendale town, by Mr. Beaumont, and which is seven miles long.

In 1878 Cumberland produced from 24 mines 2,667 tons of lead ore, containing 11,707 ounces of silver. Durham and Northumberland from 30 mines gave 16,869 tons of lead ore, containing 58,318 ounces of silver; and Westmoreland from one mine yielded 1,581 tons of lead ore, with 14,075 ounces of silver. A few of these mines are worked in the older rocks, but the bulk of them are worked in the range of hills, of Carboniferous or mountain limestone, which, from Scotland to Derbyshire, form the Pennine chain. The diagram section, fig. 89,

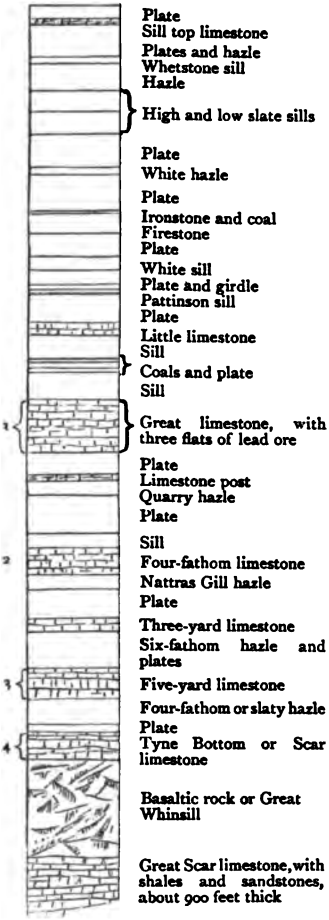


FIG. 90.—DETAIL SECTION OF THE LIMESTONE STRATA OF THE NORTH OF ENGLAND. Scale 1″ = 35 yards about.

1, Horizon of the workings on the Holyfield new vein, Halston. 2, Ditto of the rich deposits west of the Nent. 3, Ditto on the Hudgill cross vein. 4, Ditto of the silver band lead mine, Cronkley.

illustrates the general structure of these hills all along their course.

The next section, fig. 90, gives the details of the various beds composing the limestone strata, 1, and also shows the position in the series occupied by the lead ore deposits.

There are, it will be seen, four well-defined horizons of lead ore, the whole of which are above the rock known as the Great Whin Sill, and hence above the great mass of the Great Scar Limestones. The limestones, 1 2 3 4, with the intervening strata, are traversed by a vast number of lodes, which are productive in the limestone, but impoverished by various degrees in the shales and sandstones, being poorest where the strata are soft or coarse. They are also most perpendicular in the limestones, and incline to the horizontal when passing through the shales: an illustration of this is seen in the cross section of the Browngill vein, fig. 91, adapted from Wallace.

As the lodes pass through the shale beds they are often disordered, the walls are ill-defined, and little or no lead is present. Thus the Dowgang

Nent Head and Guddamgill groups of veins have been worked at various mines in the Quarry Hazle, and down as low as the Slaty Hazle, but without profitable results, although small bodies of ore were present; and rich bodies of ore which have been worked on the west side of the Nent, in the four-fathom limestone, have ceased to be productive when followed down into the Nattras Gill Hazle, and when followed down into the Slaty Hazle were pinched, and contained only small pieces of ore. Nearly the whole of the profitable and moderately productive lodes have a NW. and SE. direction, and a nearly vertical dip

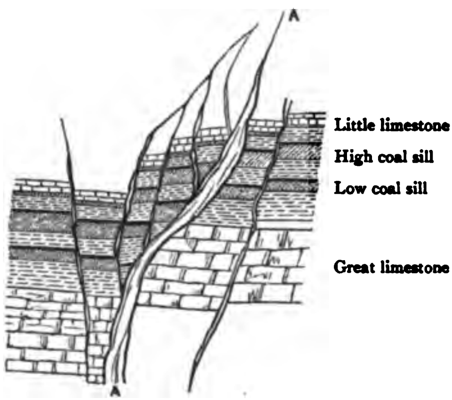


FIG. 91.—CROSS SECTION OF THE BROWNGILL VEIN.
A A, Lode.

NE. The ordinary veins are intersected by N. and S. cross veins, which are accompanied by dislocations of the strata, the beds being usually thrown up to the west. When these cross veins strike the ordinary lodes at an acute angle, the point of intersection is generally rich in ore.

The minerals associated with galena in the veins vary greatly in different parts of the district. At the Cowper's Dyke Lead Mines, carbonate of lime and fluoride of calcium fill the veins in the great limestone, the veins presenting the appearance shown in fig. 92.

1 1, Great Limestone, with crack 2 2 2 running into the lode; 3 is a central course of galena, and 3 x are lumps and spots of the same, the remainder of the lode being filled up as just described.

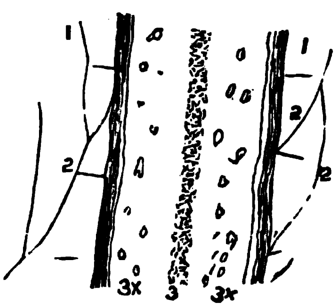


FIG. 92.—LODE IN GREAT LIMESTONE VEIN, AS AT COWPER'S DYKE.

At Nent Head fluoride of calcium is absent, its place being taken by quartz. In Alston Moor, sulphate of zinc is common, but it is absent in Weardale and Allen Heads. The lodes as they pass into the sandstones below the limestones contain more silicious and quartzose matter, and usually sulphate of zinc disappears. A good deal of carbonate of lime is also present. The latter also abounds in the Four Fathom Limestone, as well as in veins in the Tyne Bottom and Great Scar Limestone, where it occurs in slender six-sided prisms, from three to four inches long. Where the lead ore is most abundant, these prisms are most perfect. Quartz crystals are not uncommon in the limestone, as well as those of fluorspar, the whole being associated with iron pyrites. Fluorspar is generally abundant where lead ore is plentiful, although it does occur sometimes without the ore. Generally speaking the vein matter is harder on the east, in Coal Cleugh, Alston Moor, and Teesdale, than on the west, as at Allen Heads, Weardale, and Derwent. Again, at Cross Fell, on the east side of the mountain, the lodes are filled with fluoride of calcium, and on the west with sulphate of baryta. The associated minerals exist in greater variety in the lodes of the Great Limestone than in any of the other limestones.

This limestone is about twenty yards thick. It is made up of beds of limestone parted by thin layers of shale. Some of the limestone beds have, especially where much intersected by veins, become decomposed by the action of water flowing through and remaining in them, and in the cavities thus formed are found deposits of lead ore. These decomposed parts of

the Great Limestone are known as 'flats,' of which there are three—'High Flat Post,' 'Middle Flat Post,' and 'Lower Flat Post.' Sometimes these 'flats' have not been refilled with re-deposited matter, and present the appearance of caverns lined with crystals of carbonate of lime, galena, and blende. These caverns occasionally attain a large size, containing twenty cubic fathoms of space. Both the filled and the unfilled 'flats' thin off into thin layers or strings, which not unfrequently connect them with others and with the veins. They are longer horizontally than vertically, and cover large areas of the beds, those of Small Cleugh and Handsome Mea Cross Vein, shown in figs. 93 and 94 (adapted from Wallace), occupying an area of nine acres. The ore is most abundant, and the workings most extensive, in the Lower Flat.

In fig. 93 the light-shaded part shows the extent of the decomposition undergone by the limestone, and the black portions the orey ground already worked, and the fine lines are the ordinary veins.

These 'flats' in the Great Limestone, which are of considerable extent, are worked in the Dowgan Mines of Nent Head. Also in Holy Field Mines similar flats lead off from the sides of the lodes. Flats also occur in the Tyne Bottom Limestone under similar conditions, lead being distributed in paying quantities in the altered portion, but they are not much worked. Where 'flats' are not definitely formed, nearly the whole of the limestone cheeks or sides of the lodes are partially decomposed, or altered, for some distance on either side.

Yorkshire.[1]—Passing southward into Yorkshire we find in Swaledale much the same arrangement of the limestone strata as in Northumberland and Durham, as will be seen by a comparison of fig. 95, which shows the arrangement in Yorkshire, with the northern section fig. 90.

The Main Limestone, corresponding to the Great Limestone of the north, is the chief ore-bearing group of strata in

[1] See also Phillips's *Geology of Yorkshire*; *Mineral Veins of Swaledale, Yorkshire*, by Lonsdale Bradley, F.G.S.

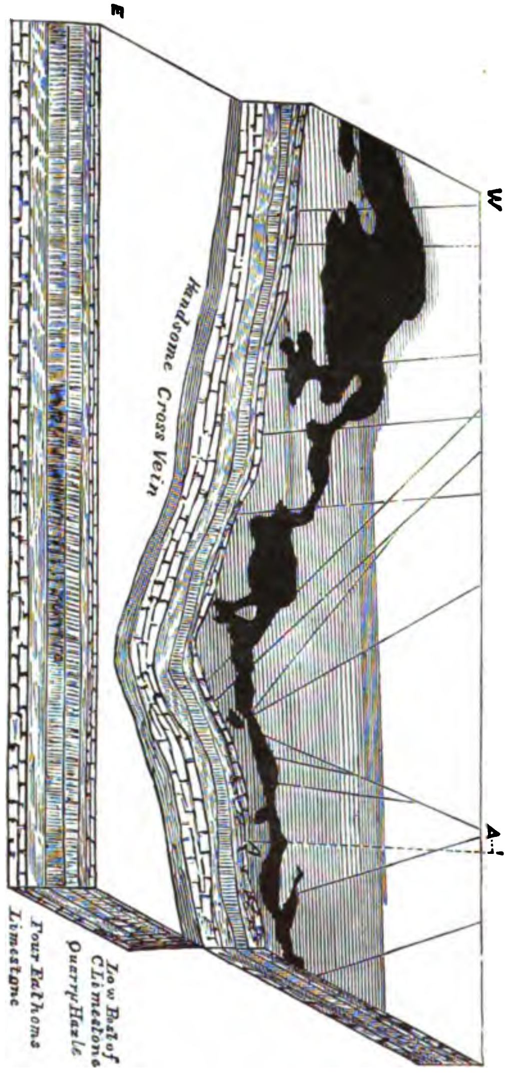


FIG 93.—PLANO-SECTION OF THE 'LOW FLAT,' WEST OF THE HANDSOME CROSS VEIN.

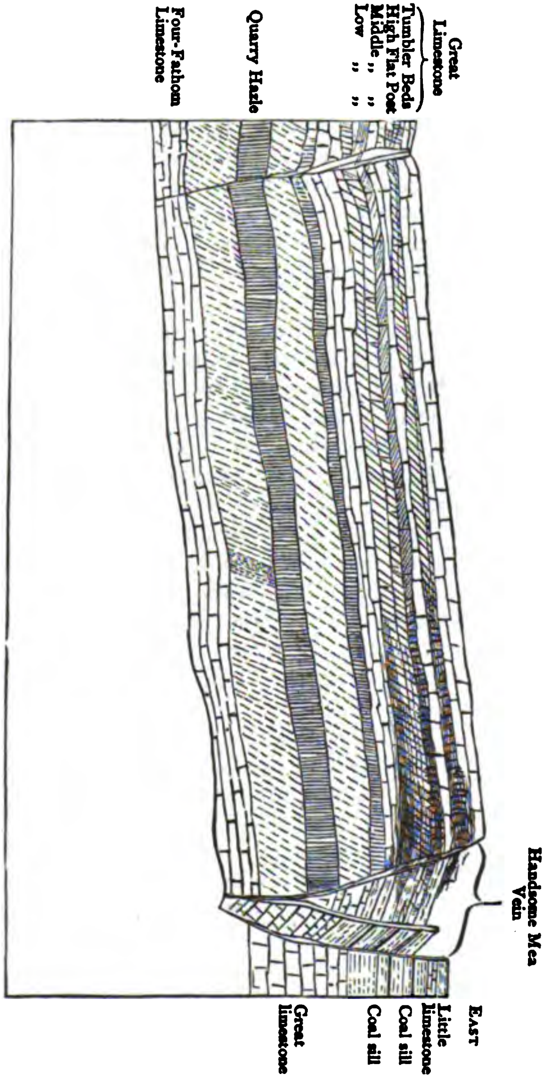


FIG. 94.—SECTION ON LINE A A, OF FIG. 93, SHOWING THE 'FLATS' IN THE GREAT LIMESTONE.

the district. It is a hard, fine, and close-grained limestone, interbedded with thin shale partings. It contains three principal layers of decomposed limestone or 'flats,' in which are also caverns containing various amounts of lead ore. These are connected by strings and veins variously prolific of ore both in the limestone and in the overlying chert. Higher still the lodes are occasionally very rich in the 'Red' Limestone, and also in the Under Sett chert and limestone. They are more rarely productive in the underlying 27 fathoms grit, when the lodes are wide. The Third Sett Limestone, corresponding to the Tyne Bottom Limestone, has not been much worked, and, as in the north, it forms the lowest limit hitherto of mining operations. The grits and plates between the beds specified are not usually productive of lead ore.

The mining district of Swaledale, which we may take as a typical one, is about fifteen miles long by six miles broad, extending from Richmond on the east, to Westmoreland on the west, and from Wensleydale on the south, to Teesdale on the north. The lodes are nearly all due east and west, very parallel to each other, and probably continuous between the mines at which they are worked. They occur in groups. Starting on the north there is a group of two lodes running through the mines, then a group of three, followed by another group of two, and at some distance farther south by another group of three.

In the SE. corner of the district, at the Grinton and Ellerton Mines, there are a few NW. and SW. lodes.

The earthy materials filling the lodes are known in York shire as 'riders.' When these consist simply of fragments of the containing rock-limestone, chert, or grit, it is called a primary rider. When it consists of these in a dissolved and reconstituted condition, as calcareous spar, fluorspar, barytocalcite, and quartz spar, it is called a secondary rider. When, finally, it consists of a loose earthy or clayey matrix, it is called a tertiary rider or lode. The substances mentioned comprise the non-metallic filling of the lodes. With these and the ore, sulphide of lead, are associated the oxides of zinc—

black and grey jack and iron pyrites. Most of the lodes have a non-metallic filling of one of the above kinds, but there are productive lodes where metallic ore fills the whole width.

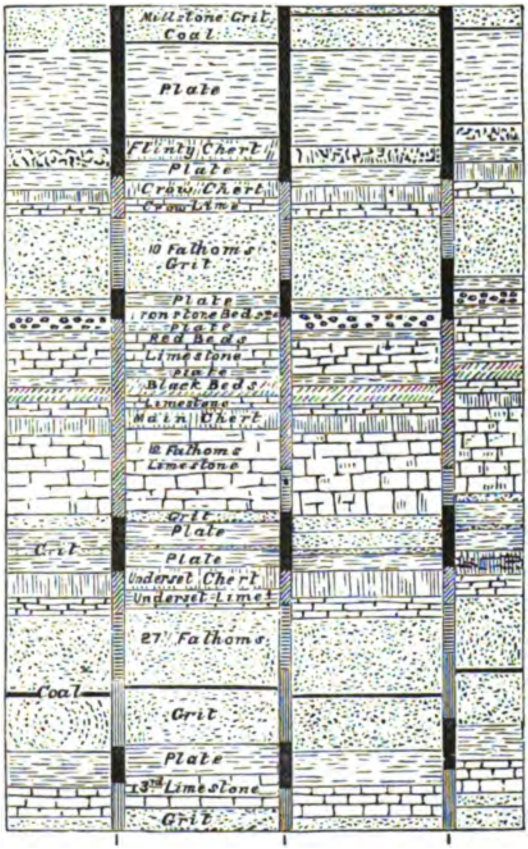


FIG. 95.—SECTION OF LIMESTONE STRATA IN YORKSHIRE, SHOWING PRODUCTIVE AND UNPRODUCTIVE PORTION OF LODES.

Scale 1" = 30 Fathoms.

1 1, Lodes. Diagonal lines, productive portions. Horizontal lines, less productive. Dark portions, unproductive. Perpendicular lines, unexplored and uncertain.

The lodes north of the River Swale are mostly true lodes, carrying strong riders, while on the south the ore lies in caverns and flats in the limestone.

Nearly the whole of the lodes are on lines of dislocation of the strata, and it has been found that the amount of the dislocation affects materially the productiveness of the lodes. An illustration of this is given in fig. 95, which is adapted from one of Mr. Lonsdale's series of similar illustrations. Where the dislocation is least, the two walls of the lodes are limestones for the greatest distance; and as this is the most favourable condition for the production of ore, a greater vertical space of ore-bearing ground is available. When the dislocation throws up a bed of grit against a bed of limestone is the next favourable condition; when a bed of shale against a bed of limestone is a less favourable condition; and when shale beds against shale beds is the least favourable condition of all others.

The percentage of ore-bearing surface to the full extent of the lodes thus varies considerably, from 61 per cent. where the dislocation is under a fathom, to 31 per cent. where the dislocation amounts to 13 fathoms. Of course, when the strata are in an undisturbed condition, the lodes are only productive, generally speaking, in the beds specified.

In the 'Top Setts' 170 points of the lodes have been returned as productive—from the crow, chert, and limestone to the black beds and thin limestone; 148 points have been productive in the 'Main Setts,' consisting of the Main Limestone and chert, and 40 in the Under Setts, composed of the Under Sett limestone and chert and the 27 fathoms grit. In 1876, Yorkshire had 54 lead mines, of which 23 made returns of ore amounting to 4,198 tons, with a proportion of 8,850 ounces of silver, or slightly over 2 ounces per ton.

Derbyshire.—Lead mining in this county is a very ancient industry. It is said that prior to the year 1289 the only lead mines were those of Derbyshire,[1] and Pryce[2] says that Edward I.

[1] McCulloch's *Commercial Dictionary.*

[2] *Mineralogia Cornubiensis.* See also Mawes' *Derbyshire*; and *Letters*, by J. B. (J. Biden), in *Mining Journal*, 1877.

brought miners from Derbyshire to work the silver mines of Devon and Cornwall. The same monarch also caused an inquisition to be made, in the sixteenth year of his reign, at Ashburn, into the rights and liberties of the Derbyshire miners. The result of this inquiry was embodied in a report, a copy of which, together with a list of the articles and customs of the Wapentake of Wirksworth, with other curious information, is contained in the 'Miner's Guide, or Complete Miner,' published at Wirksworth in 1810, by J. Cotes, and sold at that time by Crosby & Co., 4 Stationers' Hall Court.

The great mining district of the county lies between the towns of Buxton and Castleton on the north, and Cromford and Wirksworth on the south. It is about thirty miles long by about twelve miles broad; the eastern half of this width being the most productive mineral ground.

In the year 1876 there were no less than 100 lead mines in the county, 50 of which yielded ore to the extent of 2,129 tons. A number of mines yielding less than five tons each brought the quantity up to 2,264 tons, concerning which no percentage of silver is recorded. The same general arrangement of the limestone strata is continued southward into this county, and also the disposition of the lead ore and its associated minerals. There are three or four layers or courses of a basaltic-like rock, called toadstone, answering to the whinsill of the North, which run somewhat irregularly through the beds, and which pinch the lodes as they pass through them; and sometimes the lodes are quite cut off through the thickness of the dykes or beds. The various deposits of ore are locally known as 'Pipe' veins, where the ore is contained in an elongated vertical pocket; Rake veins, which are ordinary veins; and Flats, similar to those already described. There is nothing in the deposits themselves to require a special description, and I may conclude my description of the lead ore deposits of the whole of the Pennine chain of limestones with the remark that the deposits are, on the whole, richer where the beds form a synclinal trough than where they form an anticlinal ridge.

Flintshire and Denbighshire.—Dipping westward under the

Coal-measures, Permian, and New Red Sandstone strata, the limestone beds we have been considering rise again to the surface in these two counties, where they form the natural boundary between England and North Wales. From Llangollen on the south, to Flint, Holywell, and Prestatyn on the north, portions of the strata are highly mineralised with the ores of lead and zinc. Along this portion of the range there were, in 1876, in the two counties, 84 mines, of which 45 raised 5,963 tons of ore with a proportion of 26,397 ounces of silver. The bulk of the ore was raised from three mines. In Denbighshire the Minera Mine produced 3,081 tons, and in Flintshire the Talargoch Mines gave 950 tons, and the North Hendre 640 tons. In 1878 the production of the two counties was 7,845 tons.

The ore-bearing strata occupy two distinct zones in the series: first, and chiefly, in the lower pale-coloured limestones, 1 and 2 of fig. 96, which correspond to the Great Scar lime-

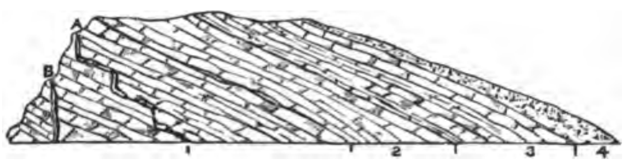


FIG. 96.—SECTION OF LIMESTONE IN FLINTSHIRE AND DENBIGHSHIRE.
Lower pale-coloured limestones. 2, Grey and yellow limestones. 3, Limestones and shales. 4, Grits and limestones. A B, Lodes.

stones of the North; and, secondly, in a lesser degree, in the grits and limestones, 4, and the uppermost part of 3, which correspond in an attenuated form to the ore-bearing grits and limestones of the northern counties. The strata between are unproductive of lead ore.

The veins are very numerous, and have a general east and west direction: those profitably worked for any length of time taking that course. There are north and south lodes of great length, which mark dislocations of the strata, but these derive their mineral wealth from the intersection and junction of the east and west lodes. A good example of a true fissure vein is seen at the Talargoch Mines, near Rhyl.

The lode runs through all the beds from the base of No. 4 to the bottom of the lowest limestone. It ranges from ENE. to WSW., dipping to the north. It varies from 3 feet to 30 feet

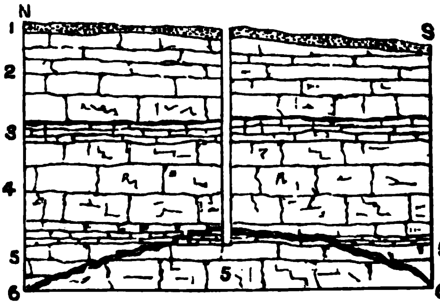


FIG. 97.—SECTION OF FLAT LODE AT NORTH HENDRE LEAD MINE, N. WALES. 1" = 100 yards.

1, Drift. 2, White limestone. 3, Bluish-black limestone and shale. 4, Black limestone. 5, Lead-bearing limestone. 6, Flat lode.

wide, being widest in the beds No. 2, of fig. 96. It has an earthy filling of carbonate of lime, cherty matter, and fragments of the adjacent strata. It contains the sulphides of lead and zinc, the latter most abundantly. The ore is richest in metallic zinc and the lead ore in silver in the beds No. 2. The lode is not productive in the beds No. 3.

There are also 'flats' of the usual kind—those formed at the junction of limestone with sandstone beds, as at Fron Fawnog; those occurring in cavities in the limestone filled with clay, with imbedded lumps of pure galena; and flat lodes like that at North Hendre, of which an illustration is given in fig. 97. In these flats, more especially in the second kind, carbonate of lead is found to a considerable extent, as at the Westminster and Queen of the Mountain Mines, where it lies at the base of the clay in the pocket or flat, filling up the hollows of the limestone beds.

SCOTLAND possesses seven lead mines, of which very little is known mineralogically. In 1877 four of these produced 2,706 tons of lead ore, which yielded 11,306 ounces of silver. An

attempt is now being made to resuscitate the Lead Hills Mines in Lanarkshire, which were formerly of considerable importance.

IRELAND.—In this island, one mine, Luganure, in the county of Wicklow, yielded in 1876 1,825 tons of lead ore, containing 6,840 ounces of silver. The mine is worked in strata of the same age as those of Shropshire, Montgomery, and Cardiganshire, already described. As there are no distinctive features to describe, this reference will conclude my description of the lead-ore deposits of the British Isles, and I will pass on to notice those of America.

CHAPTER XXVI.

LEAD—Continued.

Lead Mines of North-Eastern America—Canada—New England States—Wisconsin, Illinois, and Iowa—Carbonate of Lead in Colorado—Summary and Deductions.

EASTERN AMERICA.—Again crossing the Atlantic, and following the method hitherto pursued, I will first notice the lead mines of the country east of the Appalachian Mountains, beginning on the north and following the mines southward. We will then proceed westward to Wisconsin, Colorado, and farther west.

Canada.—In the early part of the year 1878 the Frontenac Lead Smelting Works shipped four truck-loads of lead, said to be of good quality, but we lack at present any information as to the stratigraphical conditions under which the ore was obtained.

New England States.—Lead ore deposits occur frequently in the clay slates and metamorphic rocks south-east of the Appalachian chain of mountains. For the most part these are segregated deposits, but sometimes they are found as strong, well defined lodes. The ores are a good deal mixed with inferior substances, and mining has not been very successfully pursued. Often the veins consist of barren quartz, and the segregations lie between intrusive rocks and limestones, probably of Llandeilo age. One of the best examples given by Mr. Whitney [1] was at Middleton, on the right bank of the Connecticut. The galena occurs here in a vein 10 to 20 inches wide, traversing micaceous slate. This is partly filled

[1] *Metallic Wealth of the United States.*

with quartz, that occurs in crystallised plates or combs, and is associated with calcspar, crystals of fluorspar, and sulphate of baryta. Distributed in this matrix is galena, along with blende, iron pyrites, and, rarely, yellow copper ore. The vein sends shoots along the bedding of the strata, as shown in fig. 98, which are often productive of ore for some distance from the main lode. The galena averaged 50 ounces of silver to the ton, the fine-grained yielding only one-third the quantity given by the coarse ore.

FIG. 98.—LEAD LODE IN MICACEOUS SLATE, CONNECTICUT.

New York.—The arrangement of the strata continues the same in this State, and lead ore has been obtained since the year 1835 from the veins of Ryssie, in St. Lawrence county. The principal vein—the Coal Hill Vein—is nearly perpendicular; it varies in width from 2 to 4 feet; it ranges from SSE. to NNW., and its gangue is calcareous spar, which often assumes a beautifully crystalline form. The galena occurred in a pure state as a rib about 10 inches wide, in the midst of which were fine crystals of the ore. There was not much silver, but at one time the lode was estimated at the value of 25*l.* per fathom.

Some of the finest crystals of carbonate of lime in the world have been derived from this lode, one, preserved in Yale College, weighing 165 pounds.

A similar arrangement is observed in the Union vein of the same locality, and similar deposits in veins and segregations occur in Lewis and Columbia counties.

Wisconsin, Illinois, and Iowa.[1]—Proceeding westward we reach an important lead region at the junction of these three States. It is bounded by the river Wisconsin on the north, and the Mississippi on the west, running eastward along the former river for 70 or 80 miles, and northward along the latter for about the same distance. The deposits seem to have been

[1] *Geology of Wisconsin*, Moses Strong, 1877; *Engineering and Mining Journal of New York*, vol. xxvi.; Whitney's *Metallic Wealth.*

known to the aboriginal inhabitants. Attention was attracted to the district in 1700 by Le Suer. In 1788, Dubugue, a French miner, obtained a grant of land that now includes the town that bears his name. He continued mining until his death, in 1809. Mining operations were carried on under various arrangements and with varying success till 1839, when a geological survey of the country was made by Dr. Owen and 139 assistants. In 1847 the mines yielded of metallic lead 24,145 tons. In 1853 the yield had decreased to 13,307 tons. In 1876 the production of the whole region only reached 6,812 tons.

The following is the order of the strata, with their English equivalents:

Cambro-Silurian		Bala Limestone	Niagara Limestone.
		Llandeilo Beds	Galena Limestone—Lead-bearing rock.
			Trenton Limestone—Fossils, large orthoceratites, favosites, &c.
			Sandstones, shales, and calcareous beds.
			Lower Magnesian Limestone—Lower limit of lead-bearing rocks.
Cambrian	Upper	Lingula and Tremadoc Beds	White Potsdam Sandstone.
			Fossiliferous Slates.
	Lower	Bangor Beds	Dolomitic Limestones.
			Dark Sandstones.

It will be seen that the geological horizon of the lead-bearing strata is the same as that of the Llandeilo beds of Great Britain, the difference being that in this American region there is a greater abundance of calcareous matter than there is in the British Isles. The principal mines are worked in the Galena limestone, the productive lodes penetrating at times the underlying Trenton limestone, and occasionally the Lower Magnesian limestone; but their productiveness ceases when they enter the Potsdam sandstone, corresponding to our Lingula and Tremadoc beds.

The Galena limestone is a yellowish-grey, hard, compact

crystalline rock. It contains numerous small cavities, filled with a softer material, and sometimes lined with crystals of calcite. It is thick-bedded in its upper portion, and consists of thin layers in its lower part. It contains the usual Llandeilo fossils. Distributed throughout it, but occurring more abundantly in its middle part, are layers and accumulations of flints coinciding with the bedding. The metallic deposits occur, as shown in fig. 99, in vertical cracks or crevices, as they are locally called, 1; in flats or 'flat openings,' 2; and in pockets, 3. The cracks, 1, opening out at times into cavities, as shown at A, in figs. 100 and 101.

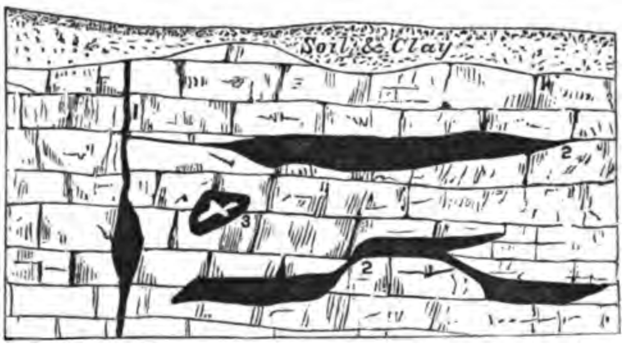


FIG. 99.—SECTION OF GALENA LIMESTONE, SHOWING LODES, FLATS, AND POCKETS, WISCONSIN.

1, Lode. 2 2, Flats. 3, Pocket.

The workings have been carried down in this limestone to a depth of about 120 feet.

The vertical veins or lodes have an east and west direction. Their usual width is from one to two feet, but they open out into cavities 30 feet across. They are filled with a dark red ferruginous clay, together with calcspar, and fragments of the adjacent rock, in which loose lumps of ore are indiscriminately distributed. In the flats the matrix is usually calcspar, in which lumps of galena occur, and which alternates in layers with calamine, blende, and iron pyrites. These flats are connected by irregular cracks with the vertical fissures, 1, bearing ore.

The ore deposits lie above a group of fossiliferous blue limestones, and it has been suggested that the gases evolved in the decomposition of so much animal matter as must have once existed, may have had a material influence in determining the precipitation of the lead from the overspreading plombiferous solution.

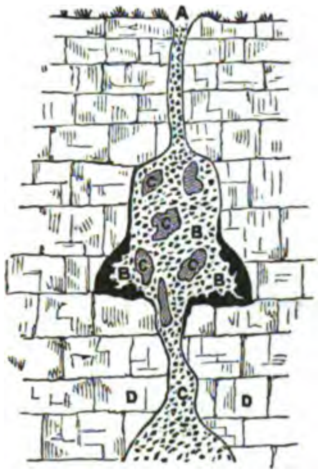


FIG. 100.—SECTION OF LEAD DEPOSIT AT WILLIAMS & Co.'s MINE, WISCONSIN.

A, Fissure, with lead ore. B, Expansion of the same. C C C, Masses of lead ore. D, Limestone.

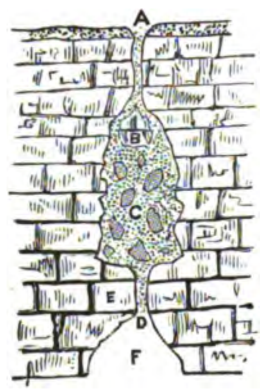


FIG. 101.—SECTION OF LEAD DEPOSIT AT BLACK'S MINE, WISCONSIN.

A, Main fissure. B, Horse of limestone. C, Expansion of crack, containing masses of lead ore. D, Limestone. E, Contraction of fissure. F, Lower expansion, as C.

The detailed section of the limestones at Mineral Point, Wisconsin, is as follows:

Chief Lead Deposit	Yellow Galena Limestone, 75 feet. Upper Lead Opening, 3 feet to 8 feet. Glass Rock or Blue Limestone, 9 feet to 12 feet.
Lead	Middle Lead Opening, 3 feet to 8 feet. Soft Spongy Limestone, 13 feet to 18 feet.
Lead	Lower Lead Opening, 4 feet to 8 feet. White Soft Galena Limestone, 1 foot to 2 feet.

Lead deposits are opening out on a large scale around the upper reaches of the Missouri and Madison rivers, but we

have not as yet many particulars concerning them. The production for 1877 reached the large amount of 22,000 tons, and it is probable that the conditions under which the ore is found are similar to those just described of the Wisconsin region, the ore lying in cracks and flats of limestones of a magnesian character, with Cambro-Silurian fossils.

The conditions under which the ore is found associated with that of silver in *Colorado*, *Nevada*, *Utah*, and the Western territories generally, have already been noticed in the description I have given of the Emma Mine, the Comstock lode, and the Ruby Hill deposits. It only remains, therefore, for me to

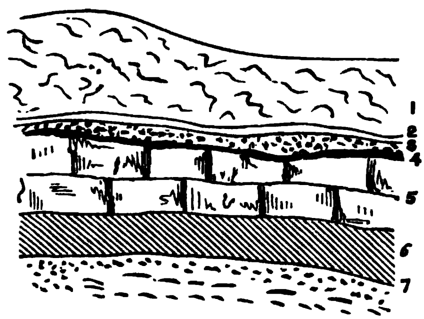


FIG. 102.—SECTION OF STRATA IN CALIFORNIA GULCH, COLORADO, SHOWING PORTION OF CARBONATE OF LEAD DEPOSITS.

1, Porphyritic rock, 12 to 100 feet thick. 2, Thin bed of white clay. 3, Carbonate of lead bed, 1 to 20 feet thick. 4, Oxide of iron, 1 to 6 feet thick. 5, Limestone. 6, Clay slates. 7, Quartzites and metamorphic rocks, resting upon gneiss.

notice the recent discovery of extensive deposits of carbonate of lead in California Gulch, Colorado.

This gulch[1] forms the bed of one of the uppermost tributaries of the Arkansas River. It lies just south of the Park portion of the Rocky Mountains, on the eastern side of the Great Divide. About sixteen years ago it was the busy scene of rich surface gold mining operations, and the miners frequently noticed the great weight of many of the stones and boulders that lay in their way; but as there was not the usual appearance of lead ore no further notice was taken.

[1] See *Engineering and Mining Journal of New York*, vol. xxv. p. 40.

The presence of carbonate of lead in these heavy stones was first recognised about three years ago by Mr. A. B. Wood, of Ann Arbour, Michigan. Further search revealed the mineral *in situ*. The region was covered with prospectors before a month was out, and the hillsides soon became riddled with shafts and levels. An examination of the majority of these shafts gives the following as the geological position of the ore, fig. 102.

The ore bed has usually been reached within a depth of 100 feet from the surface. It is found in horizontal masses extending some distance in all directions, and having a thickness of from 6 inches to 20 feet. Carbonate and sulphate of lead are the prevailing ores, but lead ore in all oxidised varieties occur. The bed varies in its composition. In places it is a compact heavy grey rock, in others it is soft and tough, but similar in colour to the first, and in places lines of darker-looking mineral run through it. The character of the ore contained is, in the first variety, 65 per cent. of lead, with from 10 to 20 ounces of silver; in the second, 65 per cent. of lead, with from 20 to 40 ounces of silver; and in the third about the same quantity of lead, with from 150 to 2,000 ounces of silver to the ton of ore, with the addition occasionally of an ounce or two of gold.

The limestones and underlying schists are for the most part in a metamorphic condition, and there can, I think, be no difficulty, from the presence of the porphyry above and the quartzites and gneiss below, in recognising their position as the equivalent of our Cambro-Silurian Llandeilo beds. The total production of lead ore in America in the year 1877 is given at 73,000 tons.

I have now enumerated the principal lead ore deposits and regions of the world, and a consideration of the phenomena and conditions described seems to lead to the following conclusions:

The lowest horizon of lead ore in workable quantities lies above that of copper and the other metals before described, being in the Llandeilo and Arenig strata of this country, and

their equivalent elsewhere. That lodes and deposits cease to be productive as soon as they enter the underlying Lingula and Tremadoc schists, and sooner where the Arenig strata are of a soft shaly nature. That the productive zone does not extend into the overlying Bala beds and strata of the Upper Silurians. That a productive zone of limited areas, as in Devonshire, and possibly in some of the Western American mines, lies in the middle limestones and slates of the Devonian group of strata. That the third and highest ordinary horizon is found in the Carboniferous limestone, this horizon being divisible into two zones, one in the pale-coloured massive limestones near the base of the series, and the other in the limestones and grits near the summit, the intervening dark limestones and shales being barren. That the largest proportion of silver is contained in the ore derived from the Cambro-Silurian strata. That both in these older strata and in those of the carboniferous series the lead ores from the lodes containing most plentifully the ores of zinc are richest in silver. That the lodes inclining most to an east and west direction, and most perpendicular in their dip, are the most persistently productive of ore. That the north and south lodes are, with a doubtful exception or two, unprofitable to work, and that the ore in these, which are cracks along lines of disturbances, lies in a rolled drifted form, and is probably in this state of subsequent origin, together with the fissures in which it lies, to that of the east and west lodes of any horizon.

CHAPTER XXVII.

ZINC.

General Remarks—Ores of Zinc—Zinc Ores of Siberia, Hungary, Silesia, Sardinia, Algeria, Belgium, Great Britain and Ireland, America, Eastern America—New Jersey—Zinc Ores of the Lead Region of Wisconsin, of the Western States—Concluding Remarks.

THE application of this metal to the useful purposes of life has been greatly extended during the last thirty years. The coating of sheet iron with it has alone vastly increased the demand for the mineral. In Great Britain and Ireland, for example, the production has increased from about 1,000 tons in 1850, to 24,485 tons in 1877.

Zinc occurs in nature combined with carbonic acid, oxygen, silica, sulphur, sulphuric acid, and more rarely with alumina. Its ores, the specific gravity of which ranges about 4·5, and their hardness 4 to 5, may be thus enumerated :

CARBONATE OF ZINC.—CALAMINE.—*Smithsonite.*—Chemical composition : pure zinc, 51·44 ; oxygen, 13·10 ; carbonic acid, 35·46. These principal constituents are often displaced by protoxide of iron to the extent of 2 to 3 ; manganese, 3 to 7 ; and magnesia, 0 to 3. In colour it ranges from colourless through dirty white, yellow, and grey, to brown. It is one of the common and most useful ores of zinc. Its varieties are—

Herrerite.—A mixture of the above with nickel oxide.

Kapnite.—The same, with 15 to 37 per cent. of protoxide of iron.

Zinc Bloom.—An earthy carbonate of zinc, containing 69 per cent. of zinc oxide with 15 per cent. of water.

OXIDE OF ZINC.—ZINCITE.—*Red Zinc Ore.*—Chemical composition: zinc, 80, oxygen, 20, varied by 3 to 12 of manganese peroxide. Blood or hyacinth red, with orange yellow streak; found at Franklin and Sterling in New Jersey in foliated masses, and laminated flakes or grains. Its variety is—

Voltzite.—Containing a proportion of sulphur, forming a link with sulphide of zinc.

SILICATE OF ZINC.—ELECTRIC CALAMINE.—*Galmei.*—Chemical composition: zinc oxide, 66·8, silica, 25·7, and water, 7·5. Colourless or white, to grey, yellow, green, brown, and blue. Occurs as columnar, fibrous, granular, and earthy. A valuable ore of zinc. Its varieties are:

Aurichalate.—Containing some zinc carbonate and copper.

Franklinite.—A mixture of zinc with manganese and iron, forming practically an ore of iron.

Hopeite, with a proportion of phosphorus; a rare mineral. Willemite, oxide of zinc, 72·85, silica, 27·15.

SULPHATE OF ZINC.—WHITE VITRIOL.—*Goslarite.*—Chemical composition: zinc oxide, 28·2, sulphuric acid, 27·9, and water, 43·9. Of a stalactitic and incrusting form. Nauseous and astringent taste, and ranging in colour from white to brown. Used in medicine and dyeing.

SULPHIDE OF ZINC.—BLENDE.—*Zinc Blende.*—*Black Jack.*—Chemical composition: zinc, 66·8, sulphur, 33·2, varied by iron 1 to 15, and cadmium 0 to 3. The most abundant ore of zinc. In colour ranging from yellow, green, red, brown, and black; of a resinous and waxy look, and from opaque to semi-transparent in appearance.

Zinc ores, as we have seen, are largely mixed with those of lead, and the mineralogical and stratigraphical conditions under which they are found, have already been pretty fully described in the chapters treating of the ores of lead. I will, therefore, only briefly describe further a few of the principal zinc ore deposits of the world.

The carbonate of zinc occurs in Siberia, Hungary, and in the mines of Saxony and Bohemia.

NORTH GERMANY.—In *Silesia*, in the district arouna Farnowitz and Benthen, the Coal-measures are developed, and there are numerous collieries and ironstone mines. Covering the Coal-measures over a considerable tract of country, and extending into Russia, is a limestone supposed to be the equivalent of the Muschelkalk, or middle member of the New Red Sandstone series. This limestone occurs in beds of ordinary thickness, and in its upper portion it frequently assumes the form of dolomite. Beds of calamine occur between the dolomite and the ordinary limestone following the line of junction. There are red and white deposits, the red being associated with red clay, and the white with white clay. The aggregate thickness of the deposit varies from 3 to 12 feet, with an average of 6 feet. The percentage of metallic zinc in the deposit averaged in 1876, 11·84 per cent., the white variety being the richest. The ores are mixed with galena, and contain a quantity of cadmium. The deposit is made up of a succession of thin strata, and the metallic ores seem as if they had been precipitated on the floor of a tranquil sea. There are also irregular deposits of calamine mixed with the ores of iron. There were 64 zinc mines in work in 1876, the production from which is given at 449,374 tons of zinc ore, of the value of 1*l.* 3*s.* 2*d.* per ton.

In the Russian portion of the deposit the production in 1874 was about 2,000 tons.

In SARDINIA are large deposits of a mixture of the carbonate with the silicate ores of zinc, which occur in Silurian limestones. The lodes or cavities are described as from five to twenty-five fathoms wide, with a north and south direction, coinciding with the strike of the beds, so that probably what are described as lodes are only mineralised beds.

The ore lies in irregular masses, which are sometimes 600 yards long, and these are connected by thin strings of ore. In places the zinc gives place to lead in depth.

Some rich lodes occur in the mountains that run across the north of Spain, near the southern shore of the Bay of Biscay, between Santandar and Asturia. The lodes range from six to eight feet wide. The lodes are well defined, and contain very pure ore—calamine, containing 52 per cent. of metallic zinc. At Bien Venido, 35 miles west of Santandar, the lodes cross each other, and form a network of calamine deposits.

In ALGERIA the zinc mine of Hamman N'bails, on the Bone and Guelma Railway, is equipped for an output of 10,000 tons a year.

BELGIUM.[1]—This is a great zinc-producing country. The principal deposits of the ores lie in the highly mineralised country between Liège, Aix-la-Chapelle, and Verviers. The geological structure of the country is as shown in fig. 103, but the rocks are greatly disturbed and contorted.

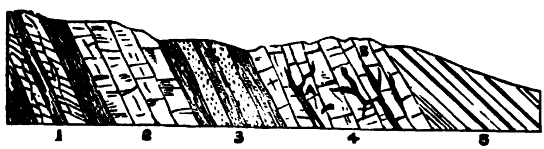


FIG. 103.—SECTION OF STRATA BETWEEN LIÈGE AND VERVIERS.

1, Quartzose slates (Devonian), containing layers and veins of hæmatite and calamine. 2, Limestones, some beds dolomitic. 3, Quartzose slates and fine-grained sandstones. 4, Limestones, with beds, pockets, and ramifications of calamine. 5, Coal-measures. A B, Zinc ore beds.

The oldest of the Belgian zinc mines is the Vielle Montagne, at the village of Moresnet, near Aix-la-Chapelle. This mine is said to have been worked by the Spaniards 400 years ago, but the actual records do not reach back beyond the year 1640. The deposit was worked by the State until the year 1806, since which date it has been worked by a public company. It occurs as filling, or as once filling, a space in the midst of limestone strata about 1,500 feet long, from NE. to SW., 700 feet wide, and from 200 to 250 feet deep. It has been worked as an open

[1] *Ann. des Mines* (4), 5, 165.

quarry, in steps or galleries all round, of which an idea is given in fig. 104.

The strata containing the zinc ores are divided into two parts by the bed of limestone, 2. The ore is of two kinds: the red containing 30 to 34 per cent. of zinc, together with a good deal of ferruginous matter, and the white yielding about 46 per cent. of zinc, and which is, of course, the most valuable. The company by which this and neighbouring deposits are successfully worked, own the Sardinian and Algerian mines just referred to, as well as some in Sweden, which are worked in lodes in older strata. The production of zinc by this company from all their mines was, in 1877, 68,095 tons, against 54,569 tons in 1876. The average production of zinc in Belgium for the years 1874–5–6 was 70,284 tons.

FRANCE.—The production of zinc in this country, as given

FIG. 104.—DIAGRAM ILLUSTRATION OF THE VIELLE MONTAGNE ZINC DEPOSIT, AIX-LA-CHAPELLE.
1 1, Limestones. 2 2, Beds of calamine and clay.

by M. Cailloux, was in 1869 1,000 tons. Possibly it is now double the amount.

GREAT BRITAIN AND IRELAND.—Turning now to the British Isles, we have already seen that the production of zinc has increased from 1,000 tons in 1850 to 24,485 tons in 1877. The price per ton of the ore ranged downwards from 4*l.* 6*s.* 6*d.* in January, to 3*l.* 12*s.* 3*d.* in December, the average price being 3*l.* 17*s.* 4*d.* The ore was produced by 57 mines, which were also lead mines. The following table[1] will show the quantity

[1] For statistics see Hunt's *Mineral Statistics of Great Britain and Ireland.*

raised in each district, and the nature of the strata whence it was derived:

No. of Mines	Locality	Cambro-Silurian and Devonian Strata	Carboniferous Limestone Strata
		tons cwts. qrs.	tons cwts. qrs.
14	Cornwall . . .	4,991 2 0	—
5	Shropshire . . .	561 13 0	—
1	Yorkshire . . .	—	4 17 0
1	Derbyshire . . .	—	2 14 1
6	Cumberland . . .	—	1,731 10 0
9	Cardiganshire . .	588 3 2	—
4	Montgomeryshire . .	2,714 16 0	—
2	Denbighshire. . .	—	2,388 0 0
3	Flintshire . . .	—	1,873 4 0
4	Carnarvonshire . .	314 1 3	—
1	Radnorshire . . .	87 0 0	—
5	Isle of Man . . .	9,043 14 2	—
1	Scotland . . .	145 0 0	—
1	Ireland	110 0 0	—
	Total . .	18,555 10 3	5,930 5 1

It will thus be seen that only one-fourth of the quantity raised was obtained from the Carboniferous limestone of this country. It is noticeable, however, that the ores from the limestones fetched the highest price. The mines producing the largest quantities were in Cornwall, West Chiverton, fig. 87, 3,660 tons; Shropshire, Roman Gravels, fig. 80, 290 tons; Cumberland, Nenthead, 1,003 tons; Cardiganshire, Florida, 286 tons; Montgomeryshire, Van, fig. 83, 2,404 tons; Denbighshire, Minera, 1,971 tons; Flintshire, Talargoch, 1,855 tons; Carnarvonshire, Pandora, 195 tons; Radnorshire, New Cwm Elan, 87 tons; and Isle of Man, Great Laxey, 8,645 tons. The Scotch mine was the East Black Craig, Kirkcudbrightshire, and the Irish, Connoree, Wicklow. By referring to the chapters on Silver and Lead, it will also be seen that the lead mines returning the largest quantities of zinc ores are also those yielding the largest proportion of silver, for instance, Great Laxey, West Chiverton, Van, Talargoch, and Minera. In Anglesea, the 'bluestone' deposit, referred to on page 143, is now opened up, and promises to yield

a large quantity of zinc, with its associated metals. Two mines in Carnarvonshire also—D'Eresby Mountain, which has a wide north and south lode, and Aberllyn, a neighbouring mine, through which the same lode is said to pass—are much spoken of at the present time as likely to be large producers of blende.

In the older rocks the zinc ores occur in lodes along with galena. In the Carboniferous limestone this is also the case, but, as in Belgium, there are in places large decomposed portions of the limestone and shale, which are partly refilled with the ores of zinc. To some extent this is the case with the Carboniferous limestone of the North Wales border, but nearly the whole of the zinc ores now raised in the district is obtained from the two great lodes worked for both lead and zinc at the Talargoch Mine near Rhyl and the Minera Mine near Wrexham.

Calamine is raised to a good extent at the Park Mines near Minera, but the common ore of zinc in the district is blende. In the lodes the blende is intermixed with galena, usually occupying the highest place, and it is richest in metallic zinc when derived from the beds 2 of fig. 96.

AMERICA.—In all the mining districts of Eastern America zinc ores are found, both associated with lead, copper, and iron ores, and also in separate deposits. An example of the

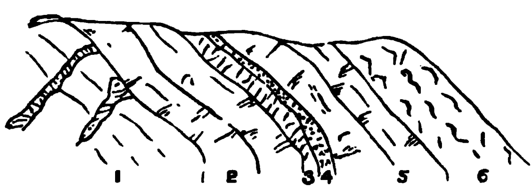


FIG. 105.—SECTION OF STRATA NEAR SPARTA, NEW JERSEY.

1, Slaty rock, with felspathic dykes. 2, Limestone. 3, Franklinite, iron ore, with zinc, 20 to 30 feet wide. 4, Red oxide of zinc, 3 to 9 feet wide. 5, Crystalline limestone. 6, Felspathic rock.

latter may be taken from a range of hills near Sparta, Sussex County, New Jersey, fig. 105. It occurs in a limestone which

is highly crystalline, probably from its connection with intrusive dykes of quartzose and felspathic ash. It is probably of Llandeilo age. The ore is made into a white oxide, which is used instead of white lead for paint.

In Pennsylvania, near Friedensville, deposits occur in beds of blue limestone of probably the same range as those just described. There are several parallel beds of an approximate aggregate thickness of 50 feet. The ore here is almost entirely a silicate of zinc of poor quality.

In the lead region of Wisconsin, Illinois, and Iowa, already described at page 235, both calamine and blende are largely associated with lead ores. The production of this region in 1876 is given as 5,000 tons of calamine and 7,000 tons of blende.

American miners are now turning their attention to the utilisation of the ores of zinc contained in the mines of the Western States, along with the ores of silver and lead. Enormous and extensive deposits, which have hitherto been neglected, are reported as occurring in close proximity to the mines of the richer metals at Georgetown and Mount Lincoln, in Colorado and Jefferson City, Montana. The ores are sulphides, and they are associated with galena and pyrites.[1] The metallic composition of these ores is shown as follows:

	Zinc	Lead	Silver
Georgetown	12	6 per cent.	100 to 1,000 ounces to the ton.
Mount Lincoln	16	7 ,,	
Jefferson City	8	10 ,,	

From the foregoing remarks it follows that zinc ores are closely associated with those of lead; that frequently a lode containing blende near the surface holds lead in depth, hence the saying of the miner, 'Black Jack rides a good horse;' that it has much the same stratigraphical range, general and particular, as lead, running rather higher into the series of rocks, lead ending in the limestones and grits below the Coal-measures,

[1] See *Engineering and Mining Journal of New York*, vol. xxv. p. 53.

and zinc continuing up to the middle of the New Red Sandstone or Triassic group; that, in addition to occurring in lodes, it occurs in large portions of the strata locally altered, and in stratified beds covering a large area, and that it was, and is, more abundant in nature than any of the metallic ores previously described.

CHAPTER XXVIII.

IRON.

Wide Distribution—Native Iron—Ores of Iron—Stratigraphical Groups of Iron Ores—Iron Ore Deposits of India—Austria—Germany—Nassau—Other German States—Sweden and Norway—Belgium—France—Spain—Algeria.

THE ores of iron are more widely distributed throughout nature than the ores of any other metal. It would be difficult indeed to say where, in one form or other, the metal is not present. We have already seen how largely it is associated with the metals we have been considering. It gives the colouring matter to most rocks, and one can hardly pick up a stone which does not contain a proportion of it. I need hardly say that it is as useful as happily it is plentiful and cheap. Nor need I here enumerate the many purposes of life to which it is applicable.

Iron occurs in a native form, and as forming an alloy with nickel, which is usually the case in meteoric iron. It also occurs plentifully in combination with oxygen and sulphur, as well as in a less degree with various acids and other ingredients.

The specific gravity of its ores ranges about 6, that of native iron reaching nearly 8, and that of the most workable ores about 5. In hardness it ranges from 4 to 7. The following are the forms and combinations in which the metal is found:

NATIVE IRON.—Occurs as meteorites, which in some instances have fallen to the earth of great size. One from Texas, which is preserved in Yale College, weighs about fifteen hundredweight. It is made up of from 90 to 92 per cent. of iron, and 8 to 10 of nickel.

In some meteorites small proportions of cobalt, copper, manganese, and tin, with occasionally a little phosphorus, are found.

COMBINATIONS OF IRON AND SULPHUR.

BISULPHIDE OF IRON.—IRON PYRITES.—Chemical composition: iron 46·7, sulphur 53·3. Colour, yellow with a brownish streak. Distinguished from copper pyrites by breaking under a blow, and in being too hard to cut with a knife. The most abundant ore of iron, of little use in iron manufacture, but forming the great source of the sulphur, sulphuric acid, copperas, and to some extent the alum, of commerce. Its varieties, differing chiefly in some particulars of shape or crystallisation, are: *Cockscomb pyrites*, *Hepatic pyrites*, *Radiated pyrites*, and *Spear pyrites.*

SULPHIDE OF IRON.—MAGNETIC PYRITES.—Chemical composition: iron 60·5, sulphur 39·5, rather redder in colour than the last, not quite so hard, and is slightly attracted by the magnet.

ARSENICAL PYRITES.—*Mispickel.*—Chemical composition: iron 34·4, sulphur 19·6, arsenic 46·0. Cobalt to the extent of from 4 to 9 per cent. sometimes taking the place of the iron. Silver-white in colour, and hard, striking fire with steel. Its variety is:

Secupyrite, which contains a less proportion of arsenic.

COMBINATIONS OF IRON AND OXYGEN.

MAGNETITE.—MAGNETIC IRON.—Chemical composition: iron 72·4, and oxygen 27·6. The most important ore of iron in the north of Europe. Strongly attracted by the magnet, being itself highly magnetic.

SPECULAR IRON ORE.—HÆMATITE.—Chemical composition: iron 70·03, and oxygen 29·97, varied by different proportions of titanium, chrome, or silica. Colour, ranging from deep red in the earthy ores, to iron black and steel grey in the purer varieties. The variations of this ore are very numerous, and comprise the following, which are all more or less valuable:

Clay ironstone.

Jaspery clay iron.—Compact, and of a brownish jaspery red colour.

Lenticular argillaceous ore.—A red ore made up of small flattened grains.

Micaceous iron.—Specular iron, with a foliated structure.

Oligiste iron, or *iron glance.*—Varieties of specular iron.

Red chalk.—A compact red mixture of iron and lime.

Red hæmatite.—Iron and clay of a deep red colour.

Red ochre.—Iron, with a preponderance of fine clay.

Specular iron.—Of a metallic lustre, and highly crystalline structure.

BROWN IRON ORE.—LIMONITE.—Chemical composition: iron 60·0, oxygen 25·6, and water 14·4, varied by silica, alumina, or phosphoric acid. A valuable and abundant ore of iron. Its varieties are:

Bog iron ore.—Occurring in lakes, bogs, and low grounds, containing from 30 to 50 per cent. of impurities, and phosphoric acid up to 11 per cent.

Brown hæmatite.—The kidney-shaped and stalactitic hæmatite ores.

Brown ochre, yellow ochre.

Brown and yellow clay ironstones.

Gotheite.—Chemical composition: peroxide of iron, and 10 water, with proportions of silica and manganese.

Turgite, Turginsk.—Peroxide of iron 94·15, and 5·85 water.

FRANKLINITE.—Chemical composition: iron 66 to 69, sesquioxide of manganese 15 to 18, and zinc 10 to 17 Its variety is:

Dysluite.—Which contains about 30 per cent. of alumina.

TITANIC IRON.—ILMENITE.—Chemical composition: peroxide of iron, with from 8 to 53 per cent. of blue oxide of titanium. *Menaccan*, *Crichlonite*, and *Mohrite* are other names for the same or similar ore. A notable variety is:

Iserine, or magnetic ironsand, which is probably magnetite, mixed with peroxide of titanium.

CHROMATE OF IRON.—*Chromite.*—*Chromic iron.*—Chemical composition: peroxide of iron 19 to 37, magnesia 0 to 10,

chrome peroxide 36 to 60, and alumina 9 to 21, with variations of 0 to 10 of silica. Used in various proportions for paints and dyes.

COLUMBITE. —*Niobite.*—Chemical composition: protoxide of iron 14 to 17, protoxide of manganese 3·7 to 4·8, niobic or culumbic acid 78 to 81, with small quantities of the oxides of tin or copper.

TUNGSTATE OF IRON AND MANGANESE.—WOLFRAM.—Chemical composition: tungstic acid 76, protoxide of iron 95 to 20, protoxide of manganese 4 to 15, with small proportions of lime and magnesia.

SILICATES OF IRON.—The compounds of the oxides of iron with silica are very numerous, but they are not of much interest commercially, and I refer the reader who desires to understand them scientifically to books devoted to mineralogy.

SULPHATE OF IRON.—COPPERAS.—Chemical composition: protoxide of iron 26, sulphuric acid 28·8, and water 45·2. Formed by the decomposition of iron pyrites.

CARBONATE OF IRON.—SPATHIC IRON.—SPARRY IRON.—CHALYBITE.—Chemical composition: protoxide of iron 62·6, carbonic acid 37·4, with small quantities of lime and magnesia, and occasionally manganese up to 25 per cent. An impure variety is the clay ironstone of the Black Band seam, which is found near the summit of the Coal measures in Great Britain.

VIVIANITE.—BLUE IRON.—Chemical composition, when pure, protoxide of iron 42, phosphoric acid 29, and water 29. Occurs occasionally in great masses in the earth under old slaughterhouses, and in indigo coloured crystals at St. Agnes in Cornwall, and elsewhere—used as a pigment.

ARSENIATES OF IRON.—There is a number of minor combinations of the oxides of iron with arsenic, but the remark made concerning the silicates is applicable to this group of iron ores.

Stratigraphically the deposits of iron ore may be comprised in three great geological groups. The first and oldest containing those from the Laurentian rocks to the Carboniferous limestone, inclusive; the second the ironstones of the Coal measures; and the third the strata from the Permian to the most recent

deposits. The whole of the deposits of iron ore belonging to these three groups are so numerous that a description of them all would be far beyond the limits of this book. It will be sufficient, I think, if I select for description a few of the more distinctive and typical examples of the ironstone deposits of the world, and I will begin, as before, in the East, with a brief reference to some of the iron ore beds of India.

INDIA.—Valuable beds of magnetic iron ore are found in the mountain Kunjamullay,[1] near Salem, on the Madras and Beypoor Railway. Fig. 106 illustrates the structure of this mountain, which rises 2,000 feet above the sea, and 1,000 feet above the surrounding plain. It is an oval-shaped hill, having its longer axis east and west. All around the hill three principal beds of magnetic iron ore crop out. These beds are each

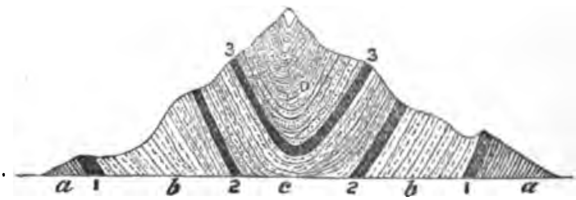


FIG. 106.—SECTION OF KUNJAMULLAY.
1, 2, 3, Iron beds. *a, b, c,* Gneissic, quartzose, felspathic, and slaty beds, with garnets.

about 50 feet thick, and there are some minor ones nearer the summit about 20 feet thick. The strata are probably of Laurentian or Cambrian age. The ore is of good quality, resembling those of the deposits of Sweden and Norway.

In the vicinity of Chandywick, in the Nerbudda Valley, in Central India, iron ore is found in irregular beds that consist of loose lumps of hæmatite, partly decomposed, that lie in hollows of the surface, and which reach a depth of ten or eleven feet. These beds seem to have been derived from veins of the same material that occur in the neighbourhood, only in an undecomposed state. One of these was formerly worked by the

[1] King and Foote, 'Geological Structure of Parts of Madras,' *Geological Magazine*, 1865, p. 173.

natives, near Manera. It is from two to ten feet thick, of rich specular iron, with very little admixture of earthy matter.

In the Himalayas, and North-West India generally, iron ores occur in clay slate, probably of Cambro-Silurian age, and in colour green, glossy blue, and mottled blue and brown. The ores lie in thin interstratified beds, that thicken out occasionally, and also in masses and lumps of ore. The district of Dhuniakote contained formerly seven or eight iron mines, which were rudely worked. The deposits here and elsewhere, as well as those associated with the Coal-measures in India, remain for European energy.

The ores are hæmatite, compact brown iron ore, and more rarely specular iron ore.

The slaty rocks become calcareous towards the top, and are surmounted by limestone. In both the calcareous slate and the limestone, there are numerous fissures and irregular cavities, which are lined and sometimes filled with the varieties of ore just named. At the junction of the rivers Rhurna and Kosila, bands of quartz containing similar deposits are interbedded in the group.

RUSSIA.—Considerable quantities of iron ore are raised in this country; the production of metallic iron in the year 1874 is given as: Ural, 1,017,000 poods, with 69,000 poods of steel; Moscow, 1,830,000 poods; South Russia, 440,000 poods; and Poland, 800,000 poods, making a total of 3,813,000 poods, or —the pood being equal to 36 English pounds—61,284 tons. The total production of iron in Russia in 1878 was given at 320,000 tons a year; but possibly this amount is exaggerated.

AUSTRO-HUNGARY.—We have already seen how largely iron ores are mixed up with other metallic ores in the mines of Hungary and the south-east of the empire, and the total production of iron in the empire is given for 1877 at 554,966 tons. In the north-west spathic iron ore—carbonate of iron—is abundantly mixed up with the lead ores of the Erzgebirge and the mountains to the south.

GERMANY.—The last remark is also true of the silver-lead mines on the Saxon side of the range, and proceeding north-west

we reach the more distinctively iron-mining State of Nassau. The annual production of iron ore in this rich little mining State amounts to nearly 200,000 tons.[1] The iron ore deposits of this State are interesting because much of the ore is found in a different geological position to any others. Fig. 107 will show the general position of these ores. They lie in hollows and abraded surfaces of the porphyritic rock, 4, and are somewhat irregular in their occurrence, so that the mining for them must be of the simplest and cheapest kind. Iron ores are also found in irregular deposits, in the limestones, and in stratified beds in the older rocks.

When Devonian limestones rest on the porphyritic rock, as they do in a large portion of the State, accretions of phos-

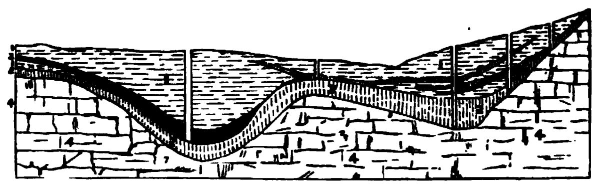


FIG. 107.—SECTION OF IRONSTONE MINE AT OBERNEISSEN, NEAR DIEZ, NASSAU. 1, Gravel and clay. 2, Red ironstone. 3, Brown ironstone. 4, Porphyritic rock.

phate of lime[2] and irregular beds of manganese, which are worked near Staffel, Weilburg, and Heckolshausen, rest similarly near the base of the driftal clay.

Prussia, *Brunswick*, *Hanover*, and *Würtemberg* are also iron-producing States; and the present aggregate annual production of iron in the whole German empire may be taken at about 360,000 tons. The production of iron ore in Prussia in 1879 was 2,955,872 tons; this quantity being raised from 549 pits, employing 21,991 hands.

SWEDEN and NORWAY.—The strata of these north-west countries of Europe consist of a succession of granitic and gneissic rocks, surmounted by slaty rocks in all stages of metamorphism

[1] Odernheimer, *Berg und Huttenwesen im Herzogthum Nassau.*

[2] D. C. Davies, 'Phosphatic Deposits of the Duchy of Nassau,' *Geol. Mag.*, 1868.

and contortion. The laminæ, or thin beds of the gneissic rocks, show numerous variations of the prevailing constituents—quartz, mica, felspar, and hornblende—and the whole series here, as elsewhere, is penetrated and disturbed by intrusive granites and greenstones. The strata belong to the Laurentian and Lower Cambrian groups, possibly to that of the former alone.

The iron ores occurring in them may be divided into three classes: 1. Deposits of pure magnetic oxide which usually occur in granite and gneiss, and also in the accompanying talcose, chloritic, and micaceous slates, and in the interstratified hornblendic rocks; 2. Specular iron ore, sometimes pure and sometimes mixed with magnetic iron, which occurs in similar rocks to those just described; and, 3. Magnetic oxide, which is generally found in argillaceous slate higher in the series of strata. We may now select a few examples of particular deposits.

The magnetic oxide is found in a very pure state at Bispberg. It occurs as a lenticular mass, the longest axis of which coincides with the dip of the slate beds in which it lies.

At Danemora, 55 miles from Stockholm, a similar deposit occurs in a ferruginous bed of slate. It extends 7,000 feet long, and 600 feet wide by 20 feet thick, and it has been worked downwards about 700 feet. The beds being highly inclined, these and similar deposits assume a roughly flattened cylindrical shape, with their widest base downwards, as shown in fig. 108.

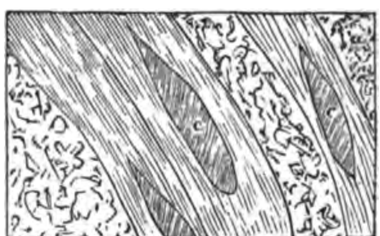


FIG. 108.—DIAGRAM SECTION OF STRATA, WITH IRON ORE, NEAR DANEMORA, SWEDEN.
a a a, Gneissic rocks. *b b b*, Slate beds. *c c c*, Deposits of magnetic iron ore.

At Uto the ore is a specular oxide, mixed with magnetite. The deposits take the form just described, fig. 108. They lie in quartzose and micaceous strata, quartz prevailing close to

the deposit. The principal deposit is 150 feet across its widest part. Its axis is vertical.

Where, owing to denuding forces, the surrounding strata have been broken and washed away, these great masses of ore assume the shape and character of ore mountains. A notable example occurs in the ore mass of Gellivara, Sweden, latitude 67°. The mass is between three and four miles long, by half a mile wide, and consists for the most part of masses of specular ore, mixed with magnetic. The principal deposit of the hill is from 100 to 500 feet thick, and is made up of a central mass of specular ore, surrounded by hæmatites. The ores from these mines contain the largest amount of phosphorus, 1·62 per cent.

Near Gellivara are the Kirunavara and Guossavara Mines, in which is a mass of ore 11,000 feet long and 500 feet across.

At Hassel, in Norway, specular ore is interstratified with slaty beds, or rather the latter are impregnated with ore to the extent of 30 or 40 per cent. At Taberg, in Smaland, beds of ore have been found in eruptive rock.

The whole of the deposits described, and others of which they are the examples, frequently occur in a series of parallel lenticular masses, as described, which extend over large belts of country.

The iron ores of Norway and Sweden are for the most part valuable, especially for the manufacture of the finer kinds of iron and steel. Analyses made from 28 districts show ores ranging from 30 to 71 per cent. of iron, the working average being 50. The amount of alumina in them is very small. Some of the magnetic ores have enough of lime and magnesia in them to do without a flux, particularly those from Danemora and Grängesberg. Phosphorus is present in small quantities in most of the ores, reaching its maximum of 1·62, as we have seen, in the ores of Gellivara. Where calcareous matter is present in the strata, there is a greater variety of minerals in the iron ore deposits.

The principal deposits worked—Perseberg, Norberg, Grangesberg, and Danemora—extend in a north-easterly direc-

tion from the northern end of Lake Wener to the Gulf of Bothnia. The important deposits of Gellivara lie, as already described, in the extreme north of the country.

Bog ores, consisting of the hydrated peroxide of iron, are found in the southern parts of Sweden. They are found in beds which sometimes reach two feet in thickness. These ores contain much phosphorus, hence they are not adapted for the manufacture of malleable iron, but receiving from the phosphorus greater fluidity when smelted, they are well adapted for the finer kind of castings for which they are used. One reason why the iron ore deposits of these countries have not been more extensively worked, is the inaccessibility of many of them; secondly, the want of cheap means of transportation and of fuel to melt the ores on the spot; and, thirdly, men of limited means have preferred to work their little concerns separately, instead of combining for common expenses.

In 1874 the total amount of hæmatite and magnetic ore raised from 696 mines was 807,887 tons, besides 4,601 tons of bog and lake ore.[1]

BELGIUM.—Returning southwards, we find a good deal of iron ore raised from the Coal-measures, the coal of which is very good for smelting, and the Belgians try to make the best use of everything.

FRANCE.[2]—In the upper part of the Valley of the Moselle, about Nancy, there is considerable deposit of ironstone as a bed in the upper part of the Lias, or at the base of the Oolitic formation. The bed seems to occupy the horizon of the Northamptonshire ironstones, as shown in fig. 113. The bed is interstratified with marl, and varies in thickness from 2 to 36 yards. The ore occurs in small grains, cemented together by lime and clay. The ores are described as oxydated hydrate ores, with occasional traces of pyrites and phosphorus up to 1 per cent. The proportion of metallic iron ranges from 20 to

[1] See *Engineering and Mining Journal of New York*, vol. xxiv. p. 149; Whitney's *Metallic Wealth*.

[2] Cailloux, *Mines et Mineraux de la France*; Jordan, *Mining Journal*, September 21, 1878, page 1036.

35 per cent. An important bed of red hæmatite occupies the same geological horizon near the towns of Privas and La Voulte, in the department of the Ardèche. The ore varies in structure from a shaly and grain-like hæmatite, with 30 per cent. of iron, to a solid, agate-like texture, containing 50 per cent.

The bulk of the iron ores used in France are, however, derived from the six great coal districts of the country; but the ironstone beds do not attain the thickness or importance of the English ironstones from the same source.

Then, in the departments of Isère, of the Pyrenees Orientales, spathic and magnetic ores and hæmatites are found in the older strata, like those of Norway and Sweden, although, from the want of means of transit, these have not been worked to any considerable extent.

SPAIN.—The mention of the Pyrenees leads us to the rich deposits of iron ore so extensively wrought in the north-west portion of this country in similar and in oolitic strata. The mines of Biscay lie some 15 or 20 miles from the port of Bilbao,[1] which, as far as trade is concerned, has been created by the iron mines. The port or ports have several piers several hundred feet long, from which vessels up to 1,600 tons burden are loaded. Some idea of the extent of the trade done may be formed from the fact that, in one day of the present year, at one of the piers, 636 trucks of ore, amounting to 3,365 tons, were discharged into the vessels lying alongside. One of the companies, the Galdames, employ 1,150 persons on their railway, pier, and mines. The mines consist of open excavations and of levels driven in the side of a mountain. The ore is red hæmatite, ranging 50 to 60 per cent. The production of this company is now 200,000 tons a year.

Above these mines are those of Orcanera and Triano, which are also huge excavations in beds of ore, as well as excavations underground. These mines produce about 1,200 tons a day, of about the same percentage as that just given. The mines belonging to Herr Krupp produce 200,000 tons yearly.

[1] See 'The Mines of Biscay,' *Mining Journal*, September 21, 1878.

The production of the whole of the mines of this region is very great, probably not less than 3,000,000 tons. Some of the mines seem to have been worked from the time of the Romans, but it is only of late years that the works have attained their present great dimensions. Iron ores are also derived to a limited extent from the Coal-measures worked in Spain.

ALGERIA.—Crossing the Mediterranean into Algeria, we find an important deposit of iron ore in the older rocks of Mokta el Hadid, thirty kilometres from Bona, on the borders of Lake Telgara.

The deposit is a bed about five yards thick, the outcrop of which forms a curved line along the face of the hills for a mile and a half in length. It dips at an angle of thirty degrees SE. and lies between a bed of mica schist below and limestone above. It yields 65 per cent. of iron. The deposit was begun to be worked in 1840. The overlying rock is taken off, and the bed is worked in steps or galleries. The yield in 1874 was 430,000 tons, which was shipped at Bona.

CHAPTER XXIX.

IRON—continued.

Iron Ore Deposits of the British Isles—Cornwall—Devon—West of Ireland—Forest of Dean—Lancashire and Cumberland—Iron Ores of the Coal-measures—Divisions of the Coal-measures, and Iron Ores of each Division—Iron Ores of the Liassic and Oolitic Strata—Of Yorkshire, Lincolnshire, and Northamptonshire.

GREAT BRITAIN AND IRELAND.—The British Isles are the largest producers of iron ore of any country in the world. The production in 1877 reached a total of 16,692,802 tons. Of this amount about 12,000 tons were from the older rocks of Devon and Cornwall; and the counties of Antrim, Donegal, and Londonderry, in Ireland, gave about 150,000 tons from the newer rocks of the NE. coast. About 2,500,000 tons were derived from the Carboniferous limestones of Somerset, Gloucester, Lancashire, and Cumberland; 6,000,000 tons from the Coal-measures, and 7,500,000 tons from the Lias and Oolites of Lincoln, Northampton, and Yorkshire. In 1878 the amount produced from all sources was 26,473,597 tons. I will describe each of the sources whence the iron is derived, beginning with the oldest.

Ironstone mining in Cornwall is of recent date. The principal mines, of which there were nine producing ore in 1877, are near the towns of Lostwithiel, Wadebridge, and in the parishes of Roche, St. Stephen's, and Ladoc. The mines of Lostwithiel were first opened in 1829. The ore of the county is a brown hæmatite, and its value last year was under 10*s.* per ton. The ore occurs in beds, more or less irregular, that lie between the strata of the older rocks.

In Devonshire there are four mines producing iron ore. The

two principal ones are Florence, yielding in 1877 3,611 tons of brown hæmatite, and Haytor, yielding 2,611 tons of magnetic oxide.[1] This mine is worked on the eastern borders of Dartmoor. It occurs in three distinct beds, as shown in fig. 109 (from Foster), which are interstratified with beds of shale and sandstone, said to be of Carboniferous age, but which, for the reasons I have already adduced, may belong to an older group. Near the beds of iron ore, hornblende enters largely into the composition of the enclosing rock, which is also sometimes made up almost entirely of actinolite. The beds are ochreous near the surface, and they have been worked for ochre. They are traceable E. and W. for a distance of three quarters of a mile. They dip at an angle of 30 degrees to the north. Dr.

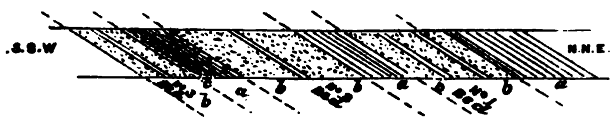


FIG. 109.—SECTION IN THE HAYTOR MINE.
Scale 1″=40 feet.
a, Silicious slate and Actinolite rock. *b*, Magnetic iron ore. *c*, Granite vein.

Foster thinks that these beds were deposited something like the Cleveland beds, and that they have subsequently been altered into magnetite by heat.

FOREST OF DEAN.—The Coal-measures of this small insulated coalfield are underlaid here, as elsewhere, by a series of sandstones known as Millstone grit, which is here of great thickness. In its cracks, permeating its softer strata, filling up joints and cavities, and lying in beds, lie the uppermost signs of the ores that have made the Forest of Dean a great iron-producing centre. The principal deposits[2] lie below the base of the Millstone grit, and in the upper part of the main mass of the mountain or Carboniferous limestone, and in this position they crop up around the edge of the coal basin, and in all probability, judging from the distance from the edge to which the

[1] Dr. Foster, *Quarterly Journal Geological Society*, vol. xxxi.
[2] See Dr. W. Watson, *Geologist*, 1858.

deposits have been worked, they lie under the whole area of this coalfield. The exact position of the deposits is shown in fig. 110.

The Whitehead limestone, 1, is 40 yards thick. It consists of red and purple sandy shales, passing upwards into the Millstone grit.

The black rock, 3, is made up of limestone, calcareous shales, and the Foreline, which passes downwards into the Old Red Sandstone.

The grey ironstone formation, 2, in which the principal iron ore deposit occurs, consists of one bed or mass of cavernous limestone, of an average thickness of 25 yards. The ore deposits within it are not evenly continuous, but occur in large masses that fill up cavities or 'churns' in the limestone, and which are connected with each other by 'leaders' or strings. The limestone is called 'crease,' and it is traversed by innumerable small

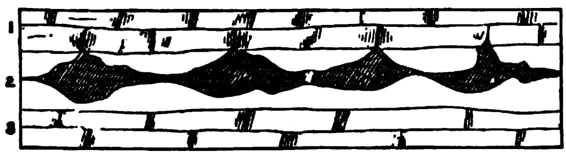


FIG. 110.—DIAGRAM OF THE IRONSTONE POCKETS IN THE FOREST OF DEAN.
1. Lowest bed of White Head limestone, called lidstone. 2, Mine measures in limestone, 25 yards thick. 3. Top of Foreline or Mountain limestone, which contains veins filled with ore, running NE. and SW.

joints that do not seem to follow any regular order. Leading joints ascend from the 'churns' into the overlying Whitehead limestone, and through the rocks above it to the daylight.

The 'churns' are near to each other, so that when the limestone in which they occur is reached, the mining for iron is not uncertain or precarious. One of these churns was 350 yards long, 14 yards high, and 12 yards broad, and is estimated to have yielded 60,000 tons of ore.

The ores are divided into: first, 'brush;' second, 'Smith Mine;' and third, 'clod.' The brush ore is a hæmatite, often yielding 80 per cent. of metallic iron, the compact kidney-shaped ore having a partly metallic lustre and a fibrous structure. It is frequently stalactitical and covered with brilliant black

crystals of hydrous-oxide of iron. The Smith Mine is a finely powdered peroxide of iron, very free from extraneous matter. It contains from 54 to 58 per cent. of iron. The clod is a marl, charged with peroxide of iron and with small fragments of hæmatite or brush ore.

The roofs of the churns are usually encrusted with stalactitic ore; concretions of compact hæmatite, coated with shining crystals of hydrous iron, lie against the walls of the churns, while

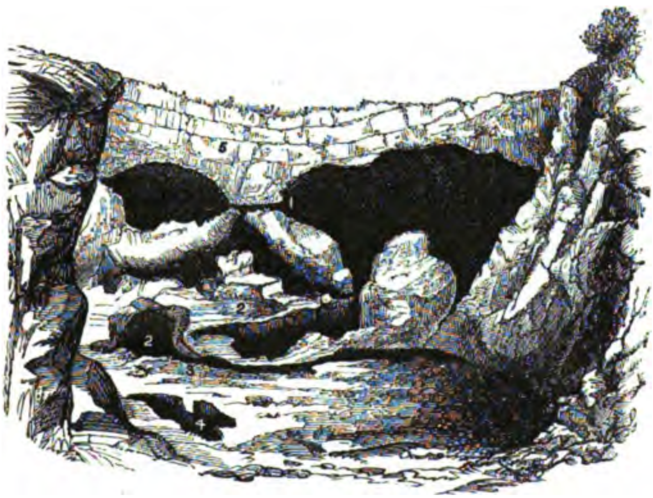


FIG. 111.
THE DEVIL'S CHAPEL, OLD PARK IRON MINES, NEAR BREAM, FOREST OF DEAN.
1, A leader. 2, Unworked ore. 3, A drift. 4, Opening made on a lead.
5, White Head limestone or lidstone.

the interior of the latter are filled with powdery hæmatite, which is held together by a slender framework of harder ore. For the most part the ores yield readily to the pick, so that they are cheaply mined. In the limestone, by which the churns are separated from each other, geodes, or large irregular balls of hæmatite, are common. So far the churns of ore have been found largest and most productive around the margin of the

coalfield. The miners have a saying, 'The smaller the leader the larger the churn.' Fig. 111, adapted from Watson, shows a section of one of the most remarkable of these churns, known as 'The Devil's Chapel,' at the Old Park Iron Mines, near Bream.

There are some ironstone deposits, known as the 'sandstone vein,' in the Millstone grit, some distance above the deposits just described. Its ore is rich in quality, but the churns are not of great magnitude, the thickness of the bed being only about five feet.

In 1877 33 mines yielded 92,974 tons of ore, of the value of 93,261*l.*, or about 13*s.* 7*d.* per ton.

Lancashire and Cumberland.—Great deposits of ironstone

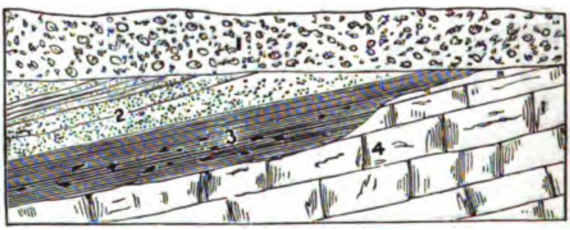


FIG. 112.—SECTION OF HÆMATITE DEPOSIT AT PARKSIDE, CUMBERLAND.
1, Drift. 2, Millstone grit. 3, Hæmatite deposit. 4, Carboniferous limestone.

are found in the Carboniferous limestone of these counties, which partake largely of the character of those just described from the Forest of Dean. The deposits are of irregular dimensions, and fill up cracks, joints, cavities, soft beds, and inequalities in the upper portion of the limestone.[1]

Fig. 112 illustrates a common mode of the occurrence of the deposits. Botroidal forms of the ore, accompanied by crystallised calcareous minerals, are also formed in cavities. The ore also occupies cavernous spaces in the limestone, and the fossils of the limestone beds are converted into hæmatite, chiefly clayey ore. The ores are hæmatite of different kinds; they yield about 60 per cent. of oxide of iron, 5 to 6 per cent.

[1] J. D. Kendall, *Q. J. Geological Society*, No. 126.

of silica, with varying proportions of alumina, lime, magnesia, and occasionally manganese. The beds of ironstone, like that in fig. 112, may represent original deposits of ferruginous mud on the sea bottom, while the churns of the Forest of Dean, and the cavities filled with iron ore in these northern limestones, seem to point to a subsequent filling by an infiltration of water passing through overlying ferruginous beds, as the deep red beds of the Permian, or the ironstone beds of the Coal-measures.

The older rocks of the district are largely charged with iron. A great piece of rock on the south side of Ennerdale Lake being called 'Iron Crag.' Ore in small quantities is obtained from these sources.

Then similar deposits to those worked in the Carboniferous limestone also occur, and are worked in the older Silurian limestones, as at Waterblean Mines in Cumberland. Here the strata are vertical, and water charged with iron seems to have penetrated and permeated the soft partings between the limestone beds.

The production of iron ore in the two counties for 1877 was 2,344,454 tons, of the value of 1,616,478*l.*, or about 13*s.* 9*d.* per ton.

Iron Ores of the Coal-measures.[1]—Usually these ores are separated in statistics from those derived from other geological formations. As, however, quite one-third of the total production of the British Isles is derived from this source, this book would not be complete without at least a brief notice of the ironstone deposits of the Coal-measures. The ores lie in regularly stratified beds or layers in the midst of the clays and shales that lie between the coal seams. Usually the iron—which seems to have been held largely in solution in the water in which these beds were deposited—has accumulated itself around some organic substance, or it fills the place once occupied by Carboniferous plants or organisms, the original material of which has perished. I divide the Coal-measures into four chief parts, in descending order, thus:

[1] See *The Iron Ores of Great Britain*: publications of the Geological Survey.

1. The Upper Coal-measures, extending from the *Spirorbis limestone* down to the sandstones and thin coals represented in South Wales by Pennant grits.

2. The Middle Sandstones and Coals. Pennant sandstones of the South Wales, Forest of Dean, and Bristol coalfields, and their equivalents elsewhere.

3. The Lower and Productive Coal-measures.

4. The Lowest or Gannister series.

Now in the whole series of the Coal-measures there are three productive and well defined horizons of iron ores. These are, in descending order:

1. The Black Band ironstone of Staffordshire, Lancashire, and Scotland, which lies near the summit of group 1, or the Upper Coal-measures. Probably its equivalent in Shropshire and South Staffordshire is the Chance Pennystone. Its ores are, where worked, a carbonate of iron, which enclose and take the place of fish and reptilian remains. It is valued as an ore of iron.

2. The clusters of ironstone beds which lie in group 3, the productive Coal-measures below the Thick coal of South Stafford, and its equivalent in the other coalfields. To this series belong the productive and extensively worked New or White mines of Stafford and Warwick, and the seams that in North Wales lie between the Main and Lower yard coals.

3. The series of ironstone beds that lie in group 4, or the Gannister series, and of which the Rosser and Pennant seams of South Wales, the Blue Flats of South Stafford, and the eleven beds that lie above the Halfyard coal in North Wales, may be taken as examples.

The ores from the two last groups are known as clayey or argillaceous ores, the percentage of iron in them ranging from 20 to 35 per cent. The ironstones of the Coal-measures of Ireland are said to be much purer than those of England, and to contain 47 per cent. of metallic iron; but they have not been much worked hitherto.

There are also associated with the coal seams bands of iron pyrites, which, when not found mixed with calcareous matter,

are used for the manufacture of sulphuric acid. The average value of the ores raised in 1877 in Great Britain from the Coal-measures was as nearly as possible 12*s.* per ton.

The Iron Ores of the Liassic and Oolitic strata.—I now pass on to notice the recently discovered deposits of iron ore in the Jurassic strata, as the two geological formations just named are called, the value and importance of which have so largely increased the iron industry and the wealth of the counties of Yorkshire, Northamptonshire, and Lincolnshire. The section, fig. 113, represents to scale the general order of the Jurassic strata of England, and shows the relative position of the iron ore beds in the three counties I have just named.

The Iron Ores of Cleveland, YORKSHIRE.—I will begin the description of the ore beds represented in the section by a notice of those worked in the Cleveland district, Yorkshire.

This comparatively modern iron ore producing district occupies the north-east portion of the county, having the sea on the east, and the River Tees on its north boundary.[1]

The lowest and principal bed of ironstones occurs, as shown in the section, fig. 113, in the marls that divide the Upper from the Lower Lias. The rock underlying it is a fine-grained, dark blue rock.

The ironstone deposits themselves consist of a varying number of seams which are interstratified with shale which is usually of a blue colour. For example: At Skelton there are four seams, which, with the accompanying shale, make up a thickness of 17 feet 7 inches; at Kildale there are seven, with shales 18 feet 4½ inches; and at Grosmont thirteen, with the shales making up a total thickness of 69 feet 2 inches.

Most of the nodules and fragments of iron ore take the place of the organic matter of fossil remains. Thus the lowest of the seams in the 'Main' deposit is known as the 'Avicula' seam, from the abundance in it of the fossil shell of that name. Higher up is the 'Pecten' seam, in which the workings are chiefly conducted. Above this is the 'Sulphur Band,' which is parted by a thin bed of shale from the overlying

[1] Bewick, *Treatise on the Cleveland Ironstones*, 1861.

'Dogger Band,' a seam that varies in thickness from 11 inches to 3 feet.

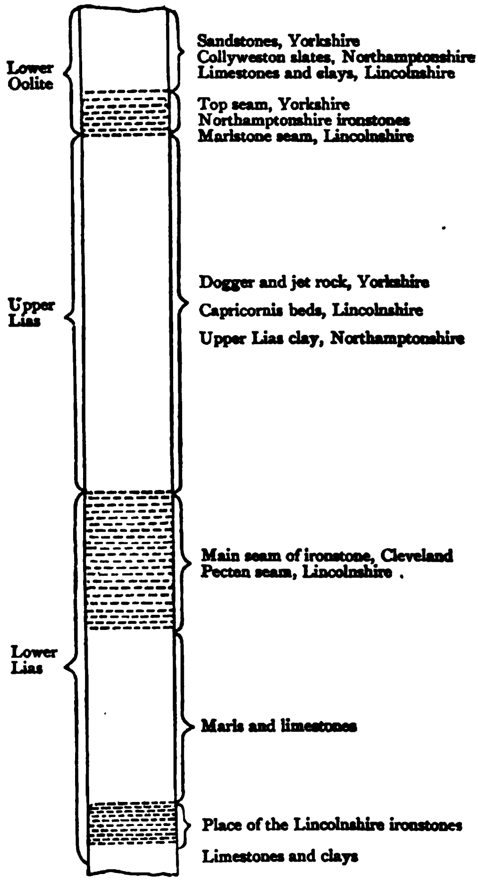


FIG. 113.—SECTION OF THE JURASSIC STRATA OF ENGLAND, SHOWING THE POSITION OF THE IRON ORES OF YORKSHIRE, NORTHAMPTONSHIRE, AND LINCOLNSHIRE.
Scale 1″ = 100 feet about.

This 'Main' deposit is thickest along the northern boundary of the district. Starting on the north-east coast line the beds

are thinnest between the Peak and Whitby. From this point to Boulby there is a great aggregate thickness of ironstone beds, but they are widely separated by shale. North of Boulby the seams begin to coalesce; they present a more compact mass at Skinning Grove, and reach their thickest and best condition about the Eston Hills, where they are 18 feet thick. Following the western boundary southward from this point there is a similar decrease of thickness to that observed on the east coast boundary; until at Kildale the deposits split up by partings of shale, so that the thickest portion is not more than 3 feet thick.

The Pecten and Avicula seams, which are sometimes 20 feet apart, come together in the region about Hutton and Grosmont. At the latter place they make a combined thickness of about 14 feet, only 6 feet 6 inches of the Pecten seam being workable. Besides the fossil shells just named, numerous terebratula are found throughout the whole deposit, which are converted into ironstone. At Normanby mines the deposit shows the following section:

	ft.	in.	
1. Top block of ironstone-Dogger	2	6	left to support the roof.
2. Pyrites band	0	2	,,
3. Main block of ironstone, including Pecten seam	8	0	Working beds.
4. Bottom block of ironstone, Avicula seam	0	9	
Total thickness	11	5	

About 200 feet above this Main deposit is the Top Seam. It is situated, as seen in fig. 113, at the top of the Lias, forming a boundary between it and the overlying Oolite. It varies in thickness from 1 to 20 feet, and, unlike the Main Seam, it generally thickens from north to south, where it attains its maximum thickness. Its general appearance is that of a coarse, hard, silicious ore, of poor quality, ranging from 15 to 20 per cent. of iron. Here and there it contains nests of fossil shells, which are richer in iron, yielding from 30 to 36 per cent. Near Rosedale Abbey it passes into a magnetic ore, although the identity of this particular deposit with the Top Seam is sometimes questioned. Successful workings have been carried on in this seam near Henderwell, on the coast, but for

the most part the profitable workings are confined to the Main Seam. The ores of the two seams are usually described as argillaceous carbonates, and the following are analyses of medium examples of the ore in each seam :

1. Analyses of twelve samples from the Top Seam at Beckhole :

Clay	20·00
Peroxide of iron	51·00
Alumina	6·00
Lime	2·92
Magnesia	19·00
	98·92
Equal to metallic iron	35·00

2. Analyses of sample from the midst of the Pecten Seam of the Main Block at the Eston Mines :

Water in combination	4·70
Phosphoric acid	2·49
Carbonic acid	26·16
Magnesia	3·19
Alumina	12·66
Silica	6·00
Peroxide of iron	3·95
Protoxide of iron	40·85
	100·00

The amount of ore raised has been nearly the same during the last three years. In 1877 it amounted to 6,284,545 tons, of the value of 1,021,238*l.* 11*s.*, or at the low price of about 3*s.* 3*d.* per ton. The ore was produced from 33 mines.

Lincolnshire.[1]—More recent is the discovery made some sixteen years ago of the ironstone bed of the NW. corner of Lincolnshire, and its introduction to commerce by Mr. R. Winn, M.P. By a reference to fig. 113 it will be seen that the Lincolnshire ironstone bed lies lower in the series of strata than the Main deposit of Cleveland. It is about 27 feet in thickness, and it abounds in Liassic fossils,—*ammonites* of the keeled varieties, together with an abundance of *cardiums*,

[1] Rev. J. E. Cross, *Quarterly Journal Geological Society*, vol. xxxi. page 115, *et seq.*

which are filled with calcite and are beautifully transparent. The base of the bed is a hard limestone band, and similar bands are intercalated with the bed and contain the fossils. Between these limestone beds are soft ferruginous beds of a dark brown colour and rubbly texture, which also contain a good proportion of brown dust. They contain but little silica, but abound in lime—rather too much so; but ores containing silica are obtained and mixed with these in the proportion of one part to eight. 3½ tons of the ore yield 1 ton of metallic iron, giving an average of about 28 per cent.

It will be seen that above this principal bed there is a thin band of ironstone known as the Pecten bed. It is a rocky band, 4 feet thick, crowded with pectens. Higher up still there is another band of ironstone known as marlstone. Although neither of these two are much if at all worked, they are interesting as appearing to be on the horizon of the Main Seam of Cleveland.

The ores are termed hydrated oxides, and last year two mines produced 508,750 tons, of the value of 76,192*l.*, or nearly 3*s.* per ton.

Northamptonshire.—This is an older iron-producing county. Its ironstones, as will be seen by the section fig. 113, appear to occupy the place of the top ironstone bed of Cleveland. At Burghley Park Ironstone Quarry the section of the deposit stands thus:[1]

Top, Collyweston slate.

	ft.	in.
Sand passing downwards into blue clay	6	6
'Best black' ironstone, cellular	2	0
Second black ironstone, less cellular and more sandy	2	0
Calcareous band	0	6
Bottom ironstone, cellular	2	0
Green ferruginous stone	1	6
Thin ferruginous band	0	9
	8	9

Upper Lias clay.

[1] 'Oolites of Northampton,' S. Sharpe, *Quarterly Journal Geological Society*, vol. xxix.

The ironstone beds appear in their thickest and richest condition at Woodford, Cranford, Wellingborough, and the neighbourhood.

In 1877 26 mines produced 1,049,806 tons, of the value of 169,981*l*., or nearly 3*s*. 3*d*. per ton.

Of an important character commercially are the iron ore deposits of the NE. of Ireland referred to. They occur between a basaltic bed above and altered limestone below, which is taken by some to be of oolitic age and by others as belonging to the older tertiary strata. It skirts the NE. coast for a length of 70 miles. The ores are chiefly aluminous ores and hæmatites, which lie in a bed in the following order:

Name	Thickness	Percentage of metallic iron
Pisolite	2 feet	50
Bole	8 ,,	20
Bottom, Lithomarge . .	30 ,,	12

The beds are not always distinct, but merge into each other, and from the whole the ores are made into an average containing 40 per cent. of metallic iron. The ores are free from phosphorus, and the presence of alumina acts as a flux. They are largely exported to Lancashire, Cumberland, and South Wales, for admixture with other ores.

CHAPTER XXX.

IRON—continued.

Ores of the Dominion of Canada—Nova Scotia—The United States. Eastern States—Missouri—Michigan and Lake Superior—Of Australasia—General Deductions.

THE DOMINION OF CANADA.[1]—The iron ores of the Dominion, especially those of Nova Scotia, are increasing in importance. Those of Nova Scotia are classified as follows:—

Geological formation	Nature of ores	Locality
Recent . . .	Bog ores . . .	Bloomfield
Traps and dykes in Triassic sandstones	Red hæmatite and magnetite . . .	Bay of Fundy
Coal-measures . .	Clay ironstones . .	Pictou Coalfield
Carboniferous limestone . .	Clay ironstones with red hæmatite, spathic iron, and limonite .	French River, Pictou
Devonian . .	Specular and magnetic ores . . .	Clement's Port, near Annapolis
Silurian . .	Red hæmatites, specular and magnetic ores	Londonderry, Pictou
Cambro-Silurian and Cambrian .	Titaniferous and specular ores	St. Mary's Bay, Digby

The Bloomfield bog ore occurs in layers of six inches to one foot thick, covered by a few inches of soil. It yields 25 per cent. of iron. It is used for mixing with other ores.

Dykes and masses of trap penetrate and are interstratified

[1] Hartington, in *Report of Progress of Geological Survey of Canada*, 1873–4; Gilpin, *Transactions North of England Mining and Mechanical Engineers*, vol. xxvi.

with the Triassic sandstones of the Bay of Fundy, and intersecting these are numerous veins and pockets of red hæmatite and magnetic ores, not exceeding a foot thick. The magnetite is also finely disseminated throughout the trap, from which, when powdered, it can be separated with a magnet. Two analyses of these ores give: metallic iron 69; oxygen 25; silica 5½, with traces of lime and magnesia.

Little attention has hitherto been paid to the clay ironstones of the Coal-measures.

In the Carboniferous limestone of Sutherlands Brook and French River, Pictou, there is a large deposit of spathic ore. It is a sparry carbonate of iron. It consists of three beds, which dip south at an angle of 60°. The lower and upper beds are from 6 to 10 inches thick, and the middle 'main' bed is from 6 feet to 10 feet thick. Where protected from the weather, the ore is of a grey colour with a pearly lustre. It contains 20 per cent. of sesquioxide, and 57 per cent. of carbonate of iron, yielding 42 per cent. of metallic iron, and it is free from phosphorus.

In the Silurian strata of Londonderry, at a distance of from 1,200 to 1,500 feet below the Carboniferous strata, is an important bed of limonite, or brown iron ore. It occurs in a mass of dolomitic limestone, 30 to 150 feet thick, which also contains layers of breccia, quartzites, and slates. These are traversed by veins of from 5 to 50 feet wide, in which the ore occurs in compact stalactitic and botryoidal masses, associated sometimes with micaceous hæmatite.

Titaniferous iron ore is found as sand in irregular beds at St. Mary's Bay, west of Digby. At Bay St. Paul, on the north shore of the Gulf of St. Lawrence, is a bed of titanic iron ore, about 90 feet thick. The ore consists of 36 per cent. of iron and 44 per cent. of titanic acid. It is described as free from manganese, sulphur, and phosphorus.

The geological survey of Canada reveals as it progresses similar deposits of iron ore right away into British Columbia, which, in time, as the country becomes populated and means of transit are provided, will become available for use.

UNITED STATES.—The deposits just described may be taken as examples of similar deposits that occur at intervals all down the eastern side of the United States, and which, although very extensively worked, do not require special description here. There is a newer deposit in Connecticut, to which I may just refer. This is the Ore Hill Mine of Salisbury. It is a vast deposit of ochres, clays, and hæmatites, of Tertiary age. The ore lies in irregular-shaped masses. It is a fibrous, massive hæmatite, which yields pig iron of the finest quality.

Missouri.—Proceeding north-west into Missouri we find beds of brown hæmatite abundantly interstratified with the older Cambrian rocks, and which are largely worked.[1]

The chief interest, however, gathers around the Iron Mountain and Pilot Knob of Missouri. The first of these is a flat-dome-shaped hill that rises about 200 feet. It is made up of red felspathic porphyry, and forms the western end of a ridge of the same character.

The surface of the hill is covered to a depth of about 15 feet with boulders of all sizes, weighing up to many tons, of nearly pure peroxide of iron. These are closely packed together, with a bright red ferruginous clay filling the interstices. Possibly these iron boulders are the sole remains of an igneous rock, which has been disintegrated and washed away, leaving these, its heaviest portions, behind. The source of these boulders had not recently been found.

Pilot Knob is a higher mountain, rising 650 feet above its base. Its structure is shown in fig. 114.

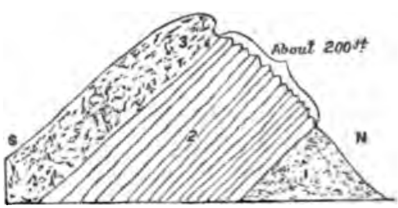


FIG. 114.—SECTION OF PILOT KNOB, MISSOURI.
1, Quartzite or silicious rock. 2, Hæmatite iron beds, alternating with silicious matter. 3, Silicious rock.

The iron beds are wide, but not continuous over a very large area. The purest of them have a somewhat slaty structure, which distinguish them from the ores of Iron Mountain.

[1] Whitney, *Metallic Wealth.*

Iron Ores of Michigan, near Lake Superior.—This is one of the most important regions for iron ore in the United States. The deposits occur as a vast succession of thin beds in the slaty and hornblendic rocks—3 B of the section, fig. 58, Chapter xviii. The intimate relationship of the beds to the adjacent strata is seen in fig. 115.

These ferruginous slates form a belt, varying from six to twenty miles wide, and stand out as successive cliffs of from 50 to 150 feet high, and which really seem mountains of iron ore. The belt extends from Lake Superior into Wisconsin, a length of about 150 miles. The highly ferruginous deposits are not continuous over the whole of this length, but occur at intervals

FIG. 115.—GEOLOGICAL POSITION OF THE IRON ORES OF LAKE SUPERIOR.
1, Granite. 2, Hornblende slates. 3, The same, with numerous thin beds of iron ore that frequently coalesce. 4, Potsdam sandstone, with lingulæ.

in areas extending from a few hundred yards to over a mile long.

Generally speaking, the deposits consist of peroxide of iron, mixed with much silicious matter. They occur as thin alternating beds, the iron at times consolidating and forming beds of great thickness. These beds are traversed by joints that cut the ore into square blocks.

In one mine the deposit shows the varieties of structure enumerated, having in the centre the laminated structure, and passing on each side into compact ore of great purity. In its purest state the ore is a compact specular ore, having profusely disseminated through it crystals of magnetic oxide. Some of the deposits are made up of very thin bands, not exceeding a

quarter of an inch in thickness, of pure fine-grained peroxide of iron and of jaspery ore. On the Cleveland location the deposit is 1,000 feet thick and one mile in length, and it is said that the supply of iron ore here alone is sufficient for the wants of the world for ages.

The iron seems to have been deposited contemporaneously with the material of the slates, and with it has received a rough sort of cleavage, like the ferruginous slates of the Lingula Flags near Tremadoc, North Wales, to which geological horizon it seems referable. Lingulæ are abundant in the overlying sandstone.

The average percentage of iron is from 60 to 70, and the ore is said to contain hardly a trace of sulphur, phosphorus, or titanic acid. The deposits were first worked in the year 1855, when the production was 1,457 tons. In 1864 the production had risen to 235,123 tons. In 1877 the production of metallic iron was 1,020,859 tons. The total production of pig iron in the United States in 1875 was 2,266,581 tons.

AUSTRALASIA.—The production of iron in the various provinces is steadily increasing, and may, at the present time, be estimated at 5,000 tons, in 1875-6 the production being as follows:

Tasmania, 1875	1,400 tons of iron.
New South Wales, 1876 . . .	2,680 ,,
Victoria, 1876	5 ,,
	4,085 tons.

One deposit may be noticed. This is an important deposit that is found as a bed between the Silurian strata and the Coal-measures of Wallerawang, 105 miles from Sydney, on the Western Railway. The deposit is made up of two beds, that contain two principal kinds of ore—magnetite or magnetic oxide, and brown hæmatite or hydrated oxide. The direction of the beds is NE. by SW. The magnetic oxide bed is from 13 to 23 feet thick, and it yields 40 per cent. metallic iron, some parts of the bed giving 70 per cent. The brown hæmatite has not been much worked, but it has been proved to a thickness of 20 feet.

Some very thick and good beds of ironstone occur in the Coal-measures of the same district; and as the coalfields of the continent are opened out, much iron ore will doubtless be derived from this source.

The foregoing description of iron ore deposits afford us illustrations of the principal ways in which the mineral is found all over the world. It will be seen that, happily for man's needs, the ores of iron have both a wider range in time, and a more profusely rich geographical distribution, than any other metallic ore.

As a rule we find the magnetic and spathose ores prevailing in the older rocks, the compact and crystallised hæmatites in the Carboniferous limestones, and the more clayey and earthy varieties in the overlying formations.

CHAPTER XXXI.

VARIOUS METALS.

Mercury Ores and Distribution—Bismuth—Nickel—Platinum—Isidium—Palladium and Tellurium.

MERCURY.

MERCURY is found in a native form, in combination with silver, and also with other substances, as chlorine, iodine, and sulphur.

NATIVE MERCURY, QUICKSILVER, is of a tin-white colour, and of a bright metallic lustre; it occurs in a fluid form as globules; it is very heavy, its specific gravity being 13·6. It becomes solid and assumes a crystalline form at a temperature of and below 39° F. It is not very abundant in nature, but occurs in most mines where the ores of the metal are obtained.

Native Amalgam.—This is a mixture, when pure, of from 64 to 72 per cent. of mercury, with from 28 to 36 per cent. of silver, and it is of a silver-white colour.

Arquerite is a variety of native amalgam, that contains only 13·5 per cent. of silver.

SULPHIDE OF MERCURY. — CINNABAR. — *Vermilion.* — Chemical composition : mercury 86·2, and sulphur 13·8. It is in colour cochineal red, with a lead grey and scarlet red tarnish, and a scarlet red streak. This is the ore from which nearly all the mercury of commerce is derived.

CHLORIDE OF MERCURY.—CALOMEL.—HORN.—QUICKSILVER.—Chemical composition : mercury 85, chlorine 15; colour, light yellow and grey, and of an adamantine lustre. The rarer ores of mercury are :

Iodic Mercury, from Mexico, of a reddish-brown colour, and *Selenide of Mercury*, a dark steel-grey ore from San Onofie, in Mexico.

CHINA.—In the far East, the Chinese work mines of cinnabar in Shensi, in a rude manner. Pits are dug in the mercurial strata, in which fires of brushwood are made, and metal derived from the surrounding strata by this process is collected after it becomes condensed in the pits.

AUSTRIA.—Near Tobria, some distance NE. of the head of the Gulf of Trieste, deposits of cinnabar were discovered in the year 1497, and they have been worked ever since. The deposits occur in the southward continuation of the Erzgebirge and Bohemian mountains, whose structure and metalliferous character have already been described. The ore seems to be contained in the schists of Cambro-Silurian or Cambrian age. The yearly production is about 250 tons.

SPAIN.—In Spain the chief mines of mercury are those of Almaden, in the province of La Mancha, on the borders of Estramdura. A considerable belt of strata stretches E. and W. from Chillon to Almadenegos, where there are very ancient mines.

The mines of Almaden are opened in three beds that run parallel to each other, and that lie something like contact deposits between Cambro-Silurian sandstones and slates above, and a metamorphic rock, locally named Fraylesca, below. This rock, Fraylesca, is a sandstone metamorphosed by contact with masses of diorite that underlie and, to some extent, penetrate it. The outcrops of some of these masses are seen on the surface not far from the mines. The three mercurial beds make an aggregate thickness of from 25 to 40 feet, and they conform to the flexuosities and stratification of the enclosing rocks. They appear as a black schist. The mercurial vapours seem to have penetrated these beds from below by sublimation, and the ores are accumulated in great masses within them, and also permeate the intervening spaces. The mines are worked to a depth of about 1,000 feet. At this depth the beds are 40 feet thick. The yield of the ore is 10 per cent., and the whole

thickness pays for taking out.[1] The production during the present century has averaged 800 tons a year.

ITALY.—At Ripa, in Tuscany, cinnabar is obtained from a cluster of small veins that range through mica slate.

GERMANY.—Mercury is obtained from the older rocks of Bavaria, of Hartenstein in Saxony, and of the Rhenish provinces, the combined production being estimated at 350 tons.

SWEDEN.—Mercury is obtained to a small extent in this country, as native amalgam and sulphide.

NORTH AMERICA.—In *California* the ores of mercury were discovered between the years 1840–5, and in 1845 a company was formed to work a deposit of cinnabar, two or three miles up one of the tributary valleys of the San Jose.[2]

The strata here consist of alternate beds of clayey shale, and layers of flinty rock. The beds are highly inclined and flexuous. The ore lies in intercalated beds of various thicknesses, and in the intervening strata there are strings and bunches of the sulphide of mercury. The strata and the ore seams are traversed by numerous veins of carbonate of lime. The cavities containing the cinnabar are also lined with carbonate of lime, in which there are small globules of bitumen. The ore is associated in a slight degree with the sulphides of iron, copper, and arsenic. Professor Hoffman gave the analysis of the ore from these mines as follows:

Mercury	67·25
Sulphur	10·33
Silica, alumina, &c.	22·55
	100·13

At the New Almaden, the principal mine in the district, the prevailing rock is a greenish talcose slaty rock. The ore is disseminated through the slate in a yellow ochreous matrix

[1] La Play, *Observations sur l'Histoire Naturelle et sur les Richesses Minérales de l'Espagne.*

[2] W. P. Black, *Silliman's American Journal of Science* (2), p. 438.

[3] Dana, *Mineralogy*, p. 288.

which forms a bed 42 feet in thickness. The richest ore is from the upper part of the bed. The rock is a metamorphic rock much tilted and contorted, but its exact age has not been ascertained.

Mexico.—In Mexico the ores of mercury are found in several places. At San Juan de la Chica, cinnabar is found in a vein varying in width from 7 feet to 2 feet. The vein traverses pitchstone porphyry, which has a spherical structure. At Durasno, cinnabar mixed with globules of native metal is found in a bed resting upon porphyry, and surmounted by beds of shaly clay that contains fossil wood and coal.

SOUTH AMERICA.—Near the villages of Azoque and Cuenca, in the province of Quito, in *New Grenada*, cinnabar is contained in a quartzose sandstone of great thickness, which also contains fossil wood and bitumen.

Peru.—The principal deposits in this country are those of the province of Huancavelica. Mercurial ores have been found in between forty and fifty places. The 'Great Mine' of Santa Barbara has been worked since 1566. Through the system of letting, formerly adopted by the government, the mine has been badly worked, and a large portion of the upper and rich workings has long since caved in. The mine presents a series of underground quarries rising in steps one above the other. The strata consist of a series of shales and sandstones about 350 feet in thickness. They lie between other sandstones and conglomerates, and dip west at an angle of 64. The production is estimated at about 900 tons a year. In the alluvial deposits near the mines, about 600 lbs. of native mercury were taken out of a ditch, one to two yards deep, and the alluvium of the neighbourhood seems penetrated with mercury. Ores of mercury are also found under similar conditions in Chili.

From the foregoing remarks it will be seen that ordinarily the geological horizon of the ores of mercury ranges from the summit of the Lower Cambrian rocks to the base of the Llandeilo beds of the Cambro-Silurian strata; that they occur in the midst of eruptive and metamorphic rocks, being mostly

associated with greenstone and porphyry; and that they are frequently accompanied by bituminous matter. Should the strata of San Jose prove of more recent origin it will be seen how very similar are the stratigraphical and petrological conditions to those in which the ores of mercury are found in the older rocks.

BISMUTH.

This metal occurs native, and also associated with carbonic acid, oxygen, silica, sulphur, and tellurium.

NATIVE BISMUTH.—Of a reddish silver-white colour, and often with red, brown, or yellow tarnish. Fuses at a temperature of 476° F., and is brittle when cold. Specific gravity 9·6 to 9·8. It is used with tin and mercury to form *mosaic gold* for ornamental purposes, with lead and tin to make toys that easily dissolve in warm liquids. A small portion is usually put into solder required for lead, pewter, and the softer metals, and it is largely employed in the manufacture of printer's type, to give a sharp, well-defined face and edge to the letters. Its ores, which are rare, are :

Sulphide of Bismuth.—Chemical composition : bismuth 81, sulphur 18·7.

Acicular Bismuth.—A sulphide of bismuth, with portions of lead and copper, with a trace of gold.

Tetradymite.—A mixture of bismuth and tellurium.

Silicate of Bismuth, or Bismuth Blende.

Cupreous Bismuth, *Wittichite.*—Chemical composition: copper 38·5, bismuth 42, and sulphur 19·5.

Bismuthite.—A carbonate of bismuth, with a little sulphate of bismuth.

The chief source of bismuth is in the mines on both sides of the Erzgebirge, where it is abundantly associated with the ores of silver and cobalt. At Schneeberg, in Austria, it is found abundantly, and forms tree-like shapes in jasper. It is found associated with copper ores near Drammen in Norway. About 8 cwt. was obtained last year from the East Pool Copper and Tin Mine, Illogan, Cornwall. It is also found in America at

Lane's Mine, Monro, and at Brewer's Mine, in Chesterfield district, South Carolina. A lode containing the mineral was also discovered in Tasmania in 1875.

NICKEL.

Except as forming from 5 to 10 per cent. of meteoric stones, nickel does not occur in a metallic form in nature, unless some masses of native iron which have been discovered in the province of Santa Catarina, in Brazil, are of terrestrial origin. These were found to contain 38 per cent. of nickel. The metal is produced artificially from its ores. It is hard and ductile, takes a good polish, and is white in colour, with a shade of light grey. Its ores have a specific gravity ranging from 5 to 8. The following are the principal varieties:

COPPER NICKEL.—NICKELINE.—*Arsenical Nickel.*—Chemical composition: nickel 43·6, arsenic 56·4; of a copper-red colour and a metallic lustre.

White Nickel.—RAMMELSBERGITE.—*Cloanthite.*—Chemical composition: nickel 28, arsenic 72, but often with small proportions of cobalt.

EMERALD NICKEL.—A carbonate of nickel containing 28·6 of water. In colour, of a bright emerald green.

There are several varieties of the above ores, but as they only consist of slightly varying proportions of the constituent minerals, they need not be here enumerated.

The whole of these ores are, as we have seen, largely associated with those of lead, copper, silver, and other ores. It is most largely combined with arsenic, and when with this mineral it is eliminated from the other metals, it is called *speiss.* It is subsequently treated by various metallurgical processes in order to separate it from the arsenic.

It is a useful metal. Alloyed in the proportion of 3 parts nickel, 8 of copper, and 3½ of zinc, it constitutes German silver, which is whitest and hardest, as it contains the largest proportion, of nickel.

In AUSTRO-HUNGARY it is associated with the ores raised in the various mining districts already described. In GERMANY

it abounds among the ores of the Erzgebirge, the production being about 100 tons annually. In *Silesian Poland* there is a production of 3 or 4 tons annually.

In SPAIN a silicate of nickel, free from cobalt, antimony, and arsenic, is found near Malagar, which contains a percentage of 3·96 of nickel.

In NORWAY a mine was worked at Espectalen formerly, from which, in two years, about 1854, 370 tons of ore were sent to England.

In GREAT BRITAIN nickel is found associated with iron at Voel Hiradig, Cwm, in Flintshire. Since 1870, 675 tons 14 cwt. of nickel iron ore have been raised on this mountain, of the value of 3,691*l.*, or about 5*l.* 10*s.* per ton. The average proportion of nickel was 2·3.

NORTH AMERICA.—*Canada.*—Nickel is found in a deposit that lies along the bedding between serpentine rock below, and a magnesian limestone above, in the township of Oxford, and province of Quebec, Canada. The strata are referred by Dr. T. Sterry Hunt[1] to the Huronian strata, the equivalent of our Cambrian group. The deposit is about 9 inches thick, and it is filled with calcite containing grains and crystals of the sulphide of nickel. There is also a good deal of chromite and chrome garnets. Grains of the nickel ore cluster on the hanging wall of the deposit, or bed, as it really seems to be. Some of the crystals are of great size and beauty, being an inch long. The proportion of nickel to the mass of the ore is from 3 to 4 per cent.

In *Connecticut* nickel is found near Chatham. The veins in which it occurs traverse mica slate. The proportion of the combined oxides of nickel and cobalt to the bulk of the stuff in the lode is 2·2 per cent., but when washed this percentage is brought up in the marketable mineral to from 13 to 18 per cent.

The principal vein is about one foot wide. It is filled chiefly with quartz, garnet, and hornblende. The principal ore is smaltine, an ore of cobalt, and this is accompanied by copper nickel, blende, galena, and copper pyrites.

[1] *Engineering and Mining Journal of New York*, vol. xxv. p. 187.

In SOUTH AMERICA nickel is found in Brazil along with other ores.

NEW CALEDONIA.—Large deposits of nickel have recently been discovered at Mount d'Or, twelve miles from Noumea, the capital of New Caledonia. The mountain rises about 1,700 feet above the sea, and is said to be a mass of nickel ore. On examination it will probably be found to consist of slaty strata, impregnated or sprinkled with the ore, and to be traversed by ramifications of veins in which the ore is concentrated. Three samples of the ore gave respectively, on analysis, 6·19, 3·26, and 7·39 of pure nickel. The first shipments of the ore to London, in the year 1875, realised 75*l.* per ton. About 3,000 tons have been shipped since 1874.

Associated with other ores as it is, the geological horizon of nickel seems to be that of copper, and the lower portions of the strata containing silver lead ores.

PLATINUM.

Native platinum is a dark grey metal with a shining metallic lustre. It is distinguished both by its extreme infusibility and malleability. It is very heavy, its specific gravity ranging from 16 to 19, and its hardness from 4 to 4·5. It occurs in small grains, and occasionally in lumps weighing several pounds. The largest specimen known weighs 21 lbs.; it was found in the Urals, and is in the Demidoff Cabinet.

Thus far the metal has been obtained from superficial sand and detritus; but it seems to have been derived originally from the same source as gold, being associated with that metal. It is always found alloyed with other metals, chiefly with the group of rare metals to which it belongs—iridium, rhodium, osmium, and palladium. The composition of a specimen from Russia showed—platinum 78·9, iridium 5·0, osmium and iridium 1·9, rhodium 0·9, palladium 0·3, copper 0·7, and iron 11·0. It was first noticed in the alluvial deposits of Choco and Barbacoa, in South America, and attention was first directed to it by Ulloa, a Spanish traveller in America, in 1736, when it was brought to this country. On account, how-

ever, of its extreme infusibility—the quality that now makes it so valuable—it remained for some time nearly useless. It was Wollaston who discovered the process of precipitating the platinum in a solution effected by nitro-chloro-hydric acid by means of chloride of ammonium. From this precipitate the platinum can be reduced to the metallic state by simple ignition. In this state it is a very fine black powder, which is strongly heated, compressed in steel moulds, and then hammered into shape.

In the far East platinum has been found in the alluvial deposits of Borneo, but the greater part of the platinum of commerce is derived from the Ural Mountains, particularly from the localities of Nischne Tagilsk and Goroblagodat. It is found, like gold, in alluvial beds. These have been traced up Mount La Martiane. This hill consists of crystalline rocks, and is supposed to be the source of the detritus with its contained platinum. The proportion of the metal obtained from 3,700 lbs. of sand is given at from one to three pounds.

The metal has also been found in North Carolina, along with gold; also in Columbia, St. Domingo, and Brazil. It is also obtained in grains from veins in the Keuper sandstones of Harmer Hill, in Shropshire, into which it was possibly drifted from the older crystalline rocks of North Wales, when these sandstones were formed.

The production of Russia is from four to five tons a year, the rest of the world yielding probably another ton, of which a quarter is derived from Borneo.

IRIDIUM.

Iridium is one of the rarer metals. It is tin-white in colour. It is usually associated with osmium, palladium, and platinum, and also, in California, with gold. It is exceedingly hard and heavy. It has been used for a long time, on account of its hardness, to tip gold pens. Latterly, it has been employed experimentally to point the drills used in rock-boring machines, its having been found of late more plentifully in the gold mines of Western America, permitting it to be used for this purpose.

PALLADIUM.

This is another member of the group of rarer metals, to which those just described belong. It was first discovered by Wollaston in 1803. It is of a light steel grey colour. Its specific gravity is 11·0. Its properties are like those of platinum, but it is hardly so valuable, and it is soluble in nitric acid. In Brazil this metal is found in pure grains, associated with native platinum, as well as intimately combined with the latter substance.

TELLURIUM.

Tellurium is one of the rarer metals. It is found native, mixed with a little gold and iron, at Facebay, in Transylvania.

It is also found in the mines of the same country combined with ochreous matter, in small white or yellowish masses, as *telluric ochre.* As *nagyagite*, or *black or foliated tellurium*, it is found both at Nagyag and Offenbanya, in the same country. In this form its composition is: lead 51 to 63, gold 6 to 9, copper and silver 1 to 13, tellurium 13 to 32, sulphur 3 to 12, and antimony 0 to 4·5. As *graphic tellurium*, or silvanite, it is found in the same district, its composition being tellurium 59·6, antimony 0·5 to 8·5, gold 26·5, and silver 13·9, with lead 0·2 to 19·5.

Tellurium has lately been found in a new and interesting combination, in the Keystone and Mountain Lion mines of Colorado, Western North America. An analysis by Dr. Genth, who has paid much attention to this class of minerals, gave the following results:

Gold	0·60
Silver	0·07
Tellurium	96·91
Vanadium	0·49
Oxide of iron	0·78
Mercury, oxide of aluminium, and potassium	1·15
	100·00

The mineral is, however, in all its forms, more interesting scientifically than commercially.

We have now reached the conclusion of the description of the metallic minerals selected for notice, and I pass on to review the principles that should guide, and the considerations that should affect, the search after metallic minerals and the exploration of mines, together with the appliances, mechanical and otherwise, by which the working of mines and the dressing of ores are facilitated.

CHAPTER XXXII.

ON THE DISCOVERY AND PROVING OF MINES.

Old Superstitions—The Strata containing Metalliferous Minerals—The Stratigraphical Zones of the different Minerals—Discovery of Mines, apparently accidental, not really so—Surface Indications—Shoding—Explorers—Prospecting—Contents and Character of Lode—Proving by Trenches, Small Shafts, Adits, Shafts, and Levels along Lode, Sumps.

A CURIOUS chapter might be written on the superstitious and magical means by which, in times past, it has been supposed that minerals might be discovered; including that belief in the magical power of the 'divining rod' which even now lingers in the minds of men whom we would suppose should know better.

Our work is more practical, and I at once proceed to notice some considerations which may at least serve to keep us from searching for metallic ores where they are not to be found; and also prevent our spending money in the prosecution of mining operations in the midst of conditions under which we cannot, ordinarily, hope for success.

This will lead me to recapitulate some of the inferences which I have already drawn at the conclusion of my account of each of the metallic ores already described.

And, first, we have seen that these minerals, with few exceptions, are confined to the older strata of the earth—from the New Red Sandstone downwards. The exceptions are, the ores of iron; the occurrence of ores where newer strata have been pierced by, or rest immediately upon, rocks of an intrusive nature, as in the deposits of the Banat in Austro-Hungary;

and where metallic ores have been drifted or otherwise derived from older strata, as in the cupreous deposits of the Triassic rocks, or of the Cretaceous strata, as in Algiers.

These are not important exceptions. Without saying, therefore, that it is an impossibility to find productive deposits of metallic ores in the Liassic, Oolitic, Cretaceous, and Tertiary strata, we may content ourselves with the reflection that, as far as the experience of the past is concerned, the occurrence of the metallic ores in these strata in paying quantities has been the exception and not the rule, and that all the probabilities are against the attainment of success in such a search. The search may consequently be left to ardent explorers who have time, money, and curiosity sufficient for the task.

It is rarely that deposits of copper in the New Red Sandstone have paid for continuous working, so that, with the exception of the ores of iron, or where the newer strata are pierced or interbedded with igneous and metamorphic rocks, it is in the strata that lie from the summit of the Millstone Grit downwards that any hopeful search for metallic minerals must be made.

There is no mistaking the locality of these older rocks. They form the elevated and rugged portions of the globe, and they have, as I have shown, all over the world a general course or direction ranging from north-east to south-west.

The search for all metallic ores except those of iron is thus practically restricted geographically to hilly regions, and stratigraphically to the rocks lying below the Coal-measures.

Further, the data we have collected from mines and mineral deposits spread over different parts of the world show that certain minerals prevail most in certain well-defined stratigraphical zones or groups of strata. Thus, leaving out of consideration the rarer metals, we find that tin occupies the lowest of these zones—its chief place being in granitic rocks, which are seen to underlie and protrude through Lower Cambrian strata; the known position of these tin-bearing granites in various other countries helping us, combined with

other considerations, to determine the age of the tin-bearing granites of Cornwall.

Nor do productive veins of tin ore appear to have been worked profitably, as a rule, in the overlying schists, into the crevices, and it may be into the composition, of which grains of ore were washed from the exposed surfaces of the older granites, while the schists were in various stages of deposition and shrinkage. We may conclude, I think, that the true home of tin is in these ancient granitic rocks.

The next zone in ascending order must be given to copper, which appears to occur in bulk in the altered Lower Cambrian strata of Anglesea, and in corresponding strata in Cornwall, America, and elsewhere.

Gold in productive quantities lies a little higher up; its place being near the junction of the Lower with the Upper Cambrian strata, and principally, perhaps, in the lowest beds of the latter. This is its position in the gold-bearing rocks of Merionethshire, North Wales; and we have seen how it is so widely disseminated throughout the Potsdam sandstone of Western North America, with its associated slates and metamorphic rocks.

Silver is associated to some extent with copper and gold in their true horizons. Indeed, silver is for the most part an associated metal. Lead and blende also make their appearance early. Thus the whole of the foregoing metals, except tin, are found intimately mixed in the bluestone deposit of Morfa-Ddu, Anglesea, but the true horizons of silver-lead and blende lie higher up in the series of strata.

The lower productive zone of lead is reached in the Llandeilo and Arenig strata. It extends upwards to the base of the Bala group, and downwards to the Tremadoc Slates and Lingula Flags. It is not worked to profit in these older rocks either above or below these limits. This, too, is the home of silver, and from this horizon it is most abundantly obtained, either mixed with lead or in its own rich ores, as in Western America.

Some locally productive lead lodes appear, as we have

seen, in the Middle Devonian strata, but the next great plombiferous belt lies near the base of the Carboniferous Limestone, as in North Wales. This belt is divided by a great thickness of unproductive ground from the uppermost zone that lies in the cherty and calcareous strata of the Yoredale rocks or basement beds of the Millstone Grit, as in Flintshire, Denbighshire, and the North of England.

Zinc, as an associated mineral, is found with copper, silver, and gold in the bluestone deposit of Anglesea, and in similar old rocks elsewhere up to the summit of the Carboniferous Limestone. Its great productive zone lies, however, as in Belgium and North Wales, in the middle beds of the Carboniferous Limestone; its next productive zone being lower down in the lead deposits of the Llandeilo and Arenig strata. To these two well-defined zones we must add the unique deposit in Silesia in the limestone beds of the Muschelkalk, as described on page 243.

Here, then, we have the accumulated results of all past experience guiding us to well-defined stratigraphical horizons, where lie the chief deposits of the different metallic ores. These horizons glide into and are connected with each other vertically, but it is evident, I think, that the chances of successful search for any particular mineral lessens as we search up or down away from the belt of strata in which it has been proved to attain its richest condition.

For example, tin disappears upwards as we ascend from its granitic home. Copper gives place to tin in depth, and it has seldom been worked long successfully above its Cambrian horizon. When lead lodes pass downwards into the underlying Lingula Flags they cease to be worked with profit. Upwards, as they enter the Bala Beds, they become charged with sulphate of baryta with occasional spots of lead, and this alteration continues up into the overlying Wenlock Shales of the Silurian group of strata, for mines worked in the old-looking shales of North Wales, as near Llangollen and near the Vale of Clwyd, yield much baryta but little lead.

Given, now, a district where, stratigraphically, the conditions

are favourable for the presence of any one of the metallic ores, how may its existence be ascertained, and the places where it lies be discovered?

As a matter of experience we have seen that many of the richest mines have been discovered by accident. The wayfarer resting in the wilds of the Saxon forest, and picking up carelessly a stone; the muleteer in Brazil scrambling after his mule, and pulling up a tuft of grass with grains of gold about its roots; the digging of a mill race leading to the race for gold in California; the laggard pilgrims attracted by the silver ores of Ruby Mountain; the curiosity excited by the great weight of the stones in California Gulch leading to the discovery of carbonate of lead. These are a few examples of what at first seems to be the accidental discovery of mines. In similar ways, by the shining grains of gold in the rivers along which they fished, were the Indians led to the discovery of gold in South America; the heavy deposits of stream tin in the rivers of Cornwall would attract the attention of the Cornish Celts, and the bog impregnated with copper the old Britons of North Wales.

But such discoveries were accidental only by reason of the previous ignorance or indifference of the dwellers in the land, or from the absence of inhabitants if there were none. For in each of the above illustrations there were natural indications which would make it plain to intelligent seekers that valuable minerals were near. Grains of gold in a river-bed, lumps of lead lying in the flats and hollows of a hilly country, springs of water charged with copper or iron, point as clearly as they can to deposits of like metals of more or less value lying near. On the whole, man has in the past been more slow to learn than nature has been to teach him the way to her hidden treasures.

It is the intelligent and persistent following of such indications that has often led to the discovery of the parent deposits.

Thus, in Brazil the miners have followed the alluvial deposits of gold to the auriferous half-formed rock cemented together with

iron, and beyond this to the real rock with its imbedded gold. The Australian has followed his recent river deposits to the more ancient deposits of the same character, and at last to the quartz reefs themselves. So with the Californian. The cupreous stream in Anglesea revealed the spot where the great copper deposit could be struck. Of later years, and only recently comparatively speaking, the Cornish man has followed his stream tin up the streams to its parent granitic rock.

The name given in Cornwall to this following of grains and fragments to the source whence they were originally derived is 'shoding,' because the mineral was traced to the point or ridge where it had been shot or shed off from the original deposit. It is soon known when this source is passed upwards, by the cessation of the appearance of the minerals sought for in the drift and soil.

When such a point is reached, should the rock be covered with driftal matter, trenches have to be cut down to the rock, so as to expose a lode, if there is one, and experience soon teaches the explorers that it is better to cut across, rather than along, the known course or direction taken by the strata of a district.

In mountainous districts the strata are already laid bare, and cut through to a great extent, by the streams that run down the hill sides. In such districts, too, there is always at least one man to be found who is a born explorer. In Wales he is often a shoemaker who cannot stick to his last; more seldom a blacksmith, and more rarely still, a gamekeeper or a shepherd. Such men are generally possessed of intelligence above the amount required for their ordinary calling in life. They are often men who love nature for her own sake. They love the freedom of outdoor life also, and they spend much time in lonely rambles in mountain regions, exploring the bed of every beck and burn. It does not detract from them to admit that they are often prompted also by the desire of acquiring money and fame, which they could not hope to get at their own trades. I know several such men. The world owes to them more than it will ever pay. Few things, too, are more enjoyable than a

walk or mountain scramble with such a man to the object of his discovery and enthusiasm, and many such walks and scrambles I have had.

These men are the pioneers of mining enterprise. They search along the beds of all the streams within their reach, noting every white vein of quartz or spar of any kind in the rock; spying out specks of pyrites which may lead to lead or copper, as the case may be, and carefully observing every local change in the structure or composition of the rocks themselves. In this way, therefore, by diligent search along mountain streams, lodes and other deposits of metallic ores are intelligently discovered.

In the Western States of America there are now organised bands of such explorers, who make systematic searches during the favourable portions of the year. They are usually experienced miners, and they have a keen eye for anything like a metallic ore. They soon learn also that, as the most persistently productive metalliferous lodes run, roughly, east and west, it is in the river beds and gorges that cross this direction in which they will have the most chances of success.

It will be readily understood from the remarks made in the first half of this chapter that a little geological knowledge, and an acquaintance with the most metalliferous zones of strata, would have saved all such explorers much vain search. For example, there would in our own country have been little need to have searched for lead in the widely spread regions covered with the deposits, many thousands of feet in thickness, that lie between the summit of the Llandeilo Beds and the middle of the Devonian series.

A metalliferous lode having been found in a suitable position, it must next be observed that it seldom shows its contents in their true condition near to the surface. There it is more or less in a decomposed condition. The iron which, in the form of pyrites, is present in most metallic lodes has become an oxide by long exposure to the atmosphere, and it presents the rusty appearance known as gossan. Of course there may be nothing in the lode below but iron pyrites, but usually there

are associated metals of more value. Hence the German rhyme—

> There is no lode like that,
> Which has an iron hat.

The kind of metallic mineral lying below, if any, may be inferred in two ways: first, from the particular horizon of strata, that is, the geological formation, and the particular part of that formation in which the lode lies; and, secondly, from the colour of the associated matter—copper being oxidised or carbonised, giving a reddish or greenish hue, tin a blackish, lead a greyish, and blende a yellowish brown colouring to the deposit. Following the lode down beyond the action of the atmosphere, the presence of each metal will become better defined, and will assume its true characteristics and proper appearance.

The question of the probability of the productiveness of a lode will be affected at the outset by some general considerations, as the following examples will show. If it is a tin lode, by the character of the granite in which it occurs—is the granite schorlaceous and partly decomposed, the condition under which, as we have seen, tin is most plentiful and is most profitably worked?

If it is a supposed auriferous quartz reef, has the quartz that massive, compact, opaque form in which, as a matter of experience, gold is least plentiful? or is it comby, drusy, sugary, and plentifully sprinkled with pyrites, which have proved the conditions in which gold has been most abundantly found?

If it is a true silver lode in the older rocks, does it lie in metamorphic rocks either as a true vein running across them, or as a parallel and contact sort of vein, like that of the Comstock, shown in fig. 39?

If copper, is it in ordinary clay slate, where usually copper is not found in payable quantities? or in metamorphic, hornblendic, and chloritic slates, like those of Cornwall and Anglesea? and are these associated with igneous rocks, like those of Africa and of the mines of Lake Superior?

If it is a lead lode in the older strata, is the lode a hard, compact, quartz lode, with only spots and strings of lead, which

is unfavourable? or a loose, sparry lode, consisting of quartz, carbonate of lime, and other sparry matter, with lead filling the interstices, which is favourable? Is it an ill-defined lode, filled with fragments hardly distinguishable from the surrounding rock, and containing very little spar, which is unfavourable? or well defined, with these fragments cemented together by plenty of quartzy and calcareous spar, and with lead sprinkled throughout, which is more favourable? If composed chiefly of blende near the surface, does the blende give place to lead in depth, so as to verify the saying which is more applicable to lead lodes in these old rocks than to those in the Carboniferous Limestone —'Black Jack rides a good horse?'

These, among other considerations, which will be suggested by a perusal of the foregoing pages, will help very materially to determine at the very beginning, or nearly so, whether a lode or other deposit is worth much further exploration.

Supposing the general conditions and appearances of a lode to be favourable, the question next arises, 'What are the best ways of proving its capabilities?' in order to decide the further question, 'Is it worth while to incur the cost of buildings, machinery, and plant?'

If a lode crosses a comparatively flat district, where it cannot be struck in depth by means of an adit level, it will be proper to proceed to prove its capabilities in one of the following ways: First, by sinking, with the help of a windlass or horse whim, small shafts along its course. This process is known in Cornwall as 'costeaning.' Secondly, by taking a shaft down the dip or hading of the lode to a depth of 10 or 20 fathoms, and at a likely-looking place to carry a tunnel right and left for some distance along the course of the lode, and, if the exploring shaft is taken deeper, by driving a similar level 10 or 15 fathoms below the first. In sinking such a shaft it should be observed in which direction the shoots or courses of ore dip. The direction taken by them will influence the driving of the levels, as well as the distance apart at which these levels should be driven. Or, thirdly, if the prospects of the lode are at first pretty good, a perpendicular shaft may be taken down

so as to cut the lode at a given depth, like the shaft at the Van Mine, only it need not be so deep, as shown in fig. 83. From the point at which it strikes the lode, levels may be taken right and left along the lode in order to prove it, as in the second case. If the prospects are very good, this shaft may be taken down of sufficient size and depth for permanent use, and adapted for pumps and cages as in a coal mine, or as shown in fig. 119. Ordinarily, however, at the commencement of a mining undertaking, it will be more prudent to take it down of a smaller size, but suitable for an air shaft when the mine is worked.

As the sinking of shafts entail the cost of winding and pumping, wherever possible a lode should be proved by means of an adit level, driven so as to cut the lode at as great a depth from the surface as practicable.

Where, as in the Cliff Mine, fig. 61, a lode runs down the face of a hill into a valley, the adit level should be taken *along* the lode, proving it every fathom it is driven. It is desirable also that sumps, winzes, or small shafts should be sunk at intervals along the floor of the level down the course of the lode to prove it in depth.

Where, however, a lode runs parallel to the face of a mountain, the adit level must be driven as a *cross cut* to intersect the lode, as in the case of the Van lode, fig. 83, or as in the case of the deep level now being driven with a view of cutting the copper deposit of Anglesea in depth, as shown in fig. 53. When the lode is reached, levels will be driven along it as in the former case.

We have already seen that lodes are more productive, even in mineralised zones of strata, in some beds than in others. Care must therefore be taken not to drive along the lode in soft strata, where the lode is comparatively unproductive, as is too often done; nor in those bands of hard rock where the lode is pinched and often poor; but in the beds which are known as usually the most productive in the district.

It will be seen, therefore, that one of the essential qualifications of a mining engineer or mine captain is a tolerably exact

knowledge of the geological structure of the district in which he works, together with the character, composition, thickness, and the amount of the inclination of the strata traversed by a lode. Otherwise he may be found spending money in vain by driving in the soft or gritty beds that lie between runs of ore like those shown in the diagram of the Snailbeach Mine, fig. 81, or in the unproductive shale beds of the Carboniferous Limestone, shown in figs. 90 and 95.

CHAPTER XXXIII.

ON THE WORKING OF METALLIFEROUS MINES.

Shafts: Vertical, Diagonal — Arrangement — Winding Compartment — Pumping Compartment—Ladders—Man-Engines—Cages and Guides—Adit Levels—Working Levels—Winzes—Stopes—Timbering—Ironstone Mining in Coal-measures—In Jurassic Strata.

I WOULD explain at this point that it forms no part of the design of this book to enumerate the details of mine carpentry or mechanics, or to give a minute description of mining tools or the way to handle them. I propose to give general principles, with selected illustrations of their application, and I would refer the unprofessional reader who may desire to pursue this part of the subject in greater detail to the excellent lectures and books mentioned below.[1]

The young professional reader will, in addition to the careful study of such books, learn such details best in actual practice at a mine.

As far as actual excavation goes, metalliferous mines are worked by means of *shafts*, *levels*, *winzes*, and *stopes*. I have already in the last chapter referred to the two first of these—shafts and levels —but it will be necessary to notice them more particularly in their relation to the permanent working of the mine.

[1] W. W. Smyth's 'Lectures on Mining,' *Mining Journal*, 1875–6; Jefferson, 'Notes on Clausthall Lectures on Mining,' *Mining Journal*, 1877–8–9; J. H. Collins, *A First Book of Mining and Quarrying* (Crosby Lockwood & Co.); William Morgans' *Manual of Mining Tools, with Atlas of Engravings* (Crosby Lockwood & Co.); G. G. Andre, *Mining Machinery, Tools, &c.* (E. & F. N. Spon).

As far as practicable the preliminary exploratory work should be planned so as to fit in with the general subsequent working of the mine, if the result should prove successful,

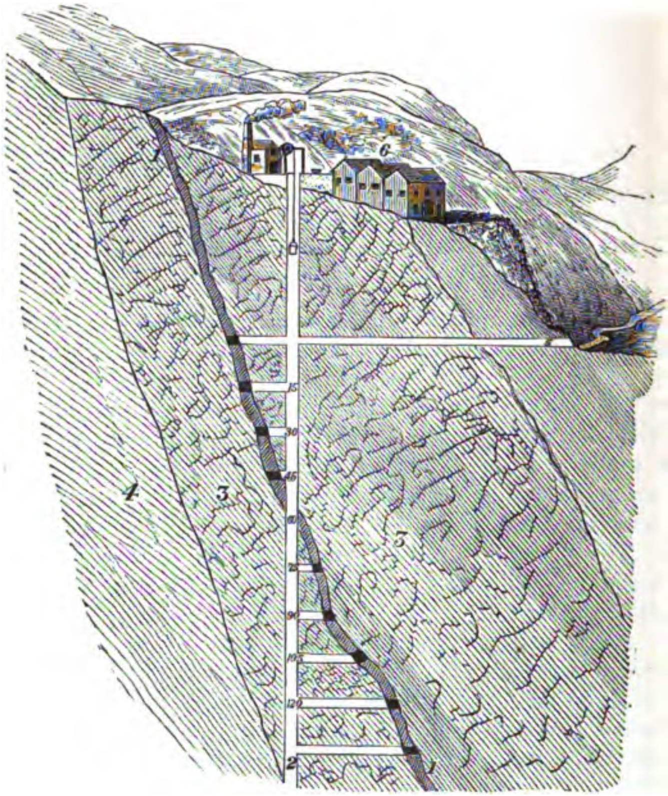


FIG. 116.—LODE WORKED BY VERTICAL SHAFT.
1, Lode. 2, Shaft, 15–120 fathoms cross cuts. 3, Productive strata. 4, Unproductive strata. 5, Adit level. 6, Dressing sheds.

and the following considerations would have to be taken into account in fixing the site and position of the works :

Character of shafts.—One of the first questions to be

decided will be the character of the proposed principal shaft of the mine. Is it to be perpendicular, or sloping down the dip of the lode?

If the dip or 'hading' of the lode is steep; if the known productive ore strata are of great thickness, as in the Van Mine, fig. 83, or if not thick the dip is very great, and the lode dips in the same direction, as shown in fig. 116, the shaft should be vertical.

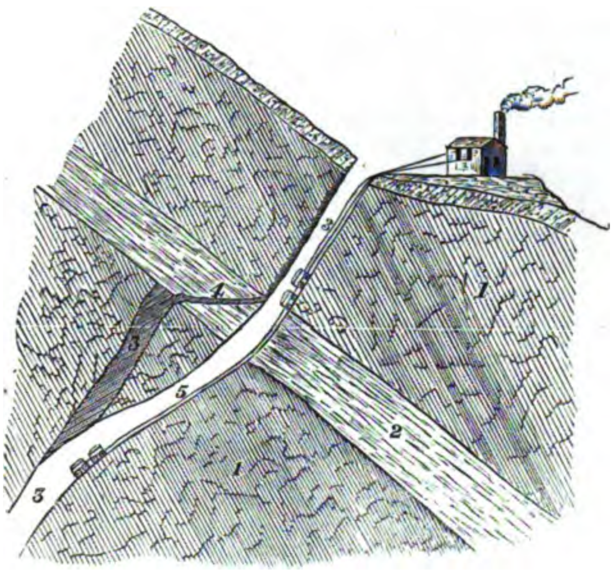


FIG. 117.—LODE WORKED BY DIAGONAL SHAFT.
1 1, Productive strata. 2, Unproductive strata. 3 3 3, Lode. 4, Fault. 5. Continuation of shaft to meet lode.

The 'hading' of the lode and the dip of the strata being known, the shaft should be placed so as to command as large a portion of the lode as possible with the smallest amount of cross-cutting. If, for example, it is known that, barring unknown faults, the mine may be worked to a depth, say of a hundred fathoms below adit, the shaft should be arranged so

as to intersect the lode 50 fathoms or half-way below the adit, leaving the latter to provide for the working of the portion of the lode that lies above it. If the lode be a flat or gently sloping lode, or if the ore-bearing strata are thin, or dip in a contrary direction to the lode, it will be better to work the mine by a sloping shaft driven down the course of the lode, as shown in fig. 117, to the base of the strata, or continued to productive strata below, where probably there may be floors and courses of ore.

In slanting shafts the angle of the incline will be affected at times by faults or by variations in the course of the lode as it passes through soft yielding strata. In such cases the good miner, having found the lode, will be careful to take the shaft down to it as nearly on one plane of inclination as possible, as illustrated in the figure 117.

These two examples of shafts will afford a clue to determine the course to be pursued in other variations of condition that may occur.

The chief points to be determined are: the amount and the direction of the dip of the strata; the amount of 'hading' and the direction of the lode; and the character of the strata in relation to the productiveness or otherwise of the lode.

A good example of a slanting shaft is seen at the Botallack Mine, Cornwall, and another, on a much smaller scale, at the Llanrwst lead mine, Carnarvonshire. Many examples occur in the Erzgebirge mining district of Germany.

The position of both kinds of shafts should also be fixed, if possible, so as to have a fall for the ore from the pit's mouth through the dressing sheds to the ore bin.

Size and arrangement of shafts.—These principal shafts of a mine should be of ample size, for (1) the winding up of the ore; (2) for pumping; and (3) for the ingress and egress of the miners. Fig. 118 is a representation of an ordinary vertical shaft. 1 is the central winding compartment; 2, the pumping division; 3, the ladder way; 4, the platform at the junction of the ladders; 5 is an intermediate level or cross-cut; and 6

shows a portion of the partition by which the ladder way must now be shut off from the rest of the shaft.

Usually, and especially in small mines, the arrangement is less complete, the shafts in limestone mining districts, for example, often being not more than 4 feet in diameter, with scarcely room for kibbles of the size of large buckets to pass each other. 12 feet by 9 feet may be given as the ordinary size of a shaft, such as is shown in fig. 118. 14 feet by 10 feet would be better wherever it is practicable.

The common winding arrangement is that shown in the figure. The kibbles being unguided, the winding has to be careful, and comparatively slow, lest the kibbles should come into collision in passing each other, which they sometimes do, a swinging and rotatory motion being almost unavoidable. In this respect metalliferous mines are behind collieries, in most of which now guides of wood or iron are fixed down the shaft for the guidance of cages, which have been substituted for loose swinging bowks or kibbles.

FIG. 118.—INTERNAL ARRANGEMENT OF SHAFT.

In some of our principal mines, the Van, for example, this better arrangement has been adopted, with great saving of manual labour and money in the extraction of the ore. It can, of course, be adopted in the case of sloping or diagonal shafts; and after a mine has attained a certain depth, or arrived

at a certain stage of development, the adoption of guides and cages should be rendered compulsory.

The chief difficulty in sinking shafts consists in passing through the superficial drift or bog that overlies the solid rock. Ordinarily this is not so thick or troublesome in metalliferous mining districts as in colliery districts. Still a good thickness of loose or boggy matter is sometimes found. The great thing in such cases is to get a set of good sinkers who know their work, and to furnish them with a plentiful supply of planks and poles. By driving these close together as a piling, and in a sloping direction, away from the centre of the shaft, as shown in fig. 119, the worst ground will be gradually got through. Of course, the looser the ground the more closely and carefully should the planks be fitted and protected from an outward as well as an inward thrust.

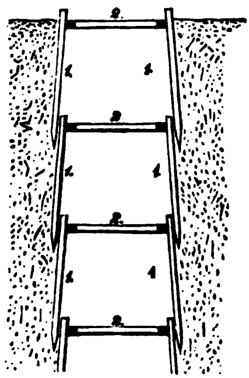


FIG. 119.—SUPPORTING SHAFT IN LOOSE GROUND.

1 1, Plank piles. 2 2, Square timber frames.

The shafts I have described are used largely for the passage of the miners to and from the workings of the mine, and the mode of this passage has been chiefly by means of ladders, as shown in fig. 118.

Formerly these ladders were of great length, and were fixed very steeply, often perpendicular, and overhanging at the top, so that nearly the whole weight of the ascending or descending miner hung upon his hands and arms, by which he had to pull himself up, or let himself down.

By the Metalliferous Mines Regulation Act of 1872, the ladders must now be fixed, as shown in fig. 118, at 'the most convenient angle which the space in which the ladder is fixed allows, and every such ladder shall have substantial platforms (4, fig. 118) at intervals of not more than 20 yards.' The separation of this part of the shaft from the other divisions is also now rendered compulsory.

Still the ascent of men from mines ranging from 100 to 200 fathoms in depth is very laborious and exhausting, especially coming as it does at the close of a hard day's work. It takes the strength out of the men, and it has been proved to induce various diseases, and to materially shorten the miner's life.

During the last hundred years mines have attained a depth previously unknown, and attention has been directed towards the discovery of some way or other by which this laborious process may be avoided.

It occurred to a German miner in the Hartz, as he looked at the action of the pump rods, whether it would not be possible by placing steps on similar rods opposite to each other to raise a man up the length of the ascending rod, and then by his stepping on a platform on the rod which had just descended he could be raised by the length of another stroke, and so on to the top of the mine; time being given between the strokes for the man to step from one platform to another.

This idea resulted in the 'Man-Engine,' Fahrekunst, as the Germans call it, which was adopted in the Hartz mines in the year 1830, and some time afterward in the Tresavean Mine in Cornwall.

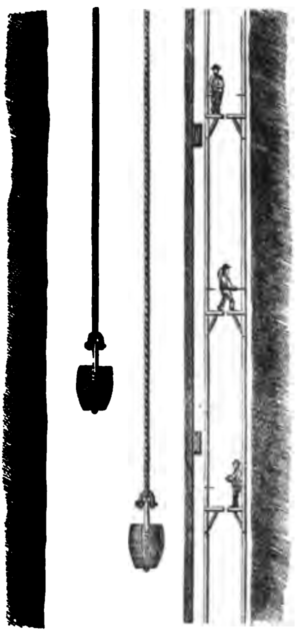


FIG. 120.—SECTION OF SHAFT, WITH 'MAN-ENGINE.'

In the latter county the machines are now formed of solid wooden rods, like pump rods. The stroke of the rods is 12 feet, and 5 strokes a minute gives 60 feet in that time, or 100 fathoms every ten minutes. The machines, of which fig. 120 will give an idea, are worked by engines placed at some distance from

the shaft, and with which they are connected by means of horizontal rods like pump rods—care being taken to avoid sudden and jerky action.

A very important man-engine is now in course of erection at the Maria Shaft at Przibram, in Bohemia, to replace one made of iron that has been in use since the year 1867. The total depth of the shaft will be over 1,000 yards. The rods for the machine are made of the best steel, so as to combine lightness with strength. The rods are made nearly square in shape, being a little longer in one direction than another. The lowest rods are slightly under 1 inch square, and the size is increased upwards, until at the top they are nearly 3½ inches square. The rods are coupled by having square projecting heads, over which are placed claw-ended coupling plates. In the lower part of the shaft the motion of the rods is protected by guides. The platforms are made of sheet iron about the seventh of an inch thick. They will hold two men, and they are placed eight yards apart. The total weight of the machine—both rods, platforms, and all appliances complete—is 77 tons; with 260 men on it the weight is about 18 tons more. The machine is worked by a steam engine with a 22-inch cylinder and a 3-foot 8-inch-stroke.

In some mines the ascent and descent of the miners are now made by cages, working between guides, as in well-appointed collieries. Objections were long entertained against the adoption of this method on the ground of the supposed difficulty of landing the men at the various levels in the mine where their work lay, but as this difficulty has been overcome in collieries, it no longer exists.

The same may be said with reference to another objection, that of the long time that would be required for taking from 200 to 300 men down a mine a few at a time. Those who have seen the same number of men go down a coal mine between five and six o'clock of a morning well know how rapidly two cages, each performing its journey in two minutes, and each cage holding six men, will take 300 men into the mine.

The time has now come, I think, when the adoption of

man-engines, cages, or any other means whereby ladder climbing can be avoided, should be made obligatory at all mines over 50 fathoms deep.

It need hardly be said that the timber and timbering used in shafts should be of the best quality and workmanship. The platforms, as long as they are used, should be firm and good, and the pump trees adequately secured according to their size and weight. The whole of the pit arrangements should be frequently examined.

The price paid for sinking shafts varies greatly according to the nature of the ground and the inflow of water. In ordinary ground a shaft 14 feet by 10 feet should be sunk and

FIG. 121.—SECTION OF ENTRANCE TO LEVEL, SHOWING METHOD OF TIMBERING.
1 1, Roof piles. 2 2, Strong timbering. 3 3 3, Side planks or 'polings.' 4, Loose ground

secured for 15*l.* per yard—carpentry, gearing, and pumps being, of course, extra.

LEVELS.—*Adit levels.*—The adit level, as I have already pointed out, is driven at as low a point on the ground as possible. It is intended to serve the double purpose of draining the loose surface ground above it, and for working the upper portion of the mine. Seven feet high and 6 feet wide is a convenient size, and the price paid for driving it will range from 4*l.* 10*s.* per fathom, in shale and slaty rock, to 18*l.* or 20*l.* in compact felspathic rock or rolled greenstone. There should be just fall enough outwards for the water to run off, and the level should have spaces at intervals for the passing of the tram waggons.

As in the case of a shaft, the chief difficulty in driving a level is in the loose ground at its entrance. This should be cut

down as far as practicable, and the level approached by a good open cutting with sloping sides. If further difficulty is found, the roof may be secured by piles driven in, as shown in fig. 121, which should be placed high enough for the permanent roadway to be formed underneath them. When made, the entrance should be well secured, which may be done with poles, as shown in fig. 122, or by masonry, as in fig. 123.

Ordinary working levels.—One of the first things to be determined concerning ordinary levels is the distance at which they should be driven from each other. Usually in mines in

FIG. 122.—TIMBERED ENTRANCE TO LEVEL.

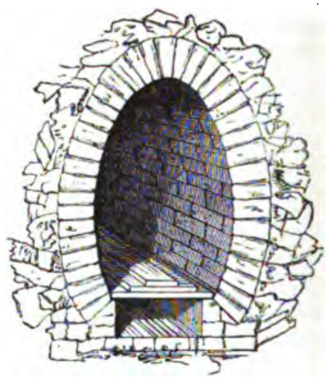


FIG. 123.—STONE ENTRANCE TO LEVEL.

this country that distance has hitherto been 10 fathoms. Latterly, in some important mines, the Van for instance, fig. 83, the distance has been increased to 15 fathoms. The Americans in their larger mines have adopted 20 fathoms as the distance.

If the ore lies in flat strings or floors, the lesser distance is more likely not to miss any of them. If the courses run down steeply, as at Snailbeach, fig. 81, there is not the same necessity for driving the levels so close together.

The distance apart to be adopted must therefore depend upon the character of the mine; but, wherever practicable, the

greater distance should be adopted. It must be remembered that the ore in each square of the lode, bounded on either side by shafts or winzes, and above and below by levels, has to bear the cost of driving one level and one winze, consequently the smaller the square the greater the proportion of cost per ton chargeable on the ore for forming these.

To take an example. A square, 10 fathoms by 10 fathoms, of a lode, yielding an average of 2 tons of ore to the fathom, contains within it 200 tons of ore. Taking the cost of driving the level with all expenses at 7*l.* 10*s.* per fathom, and the cost of the winze at the same price, the total cost is 150*l.*, which makes a charge of 15*s.* per ton on the ore contained within the square. If the area is enlarged to 15 fathoms square, the cost per ton will be 11*s.* 3*d.*; if to 20 fathoms, the cost will be reduced to 7*s.* 6*d.*; and as cross-cuts have to be made, these figures do not represent the whole of the saving effected. Thus it is clear that the farther apart the levels can be kept, compatibly with the effectual working of the mine, the cheaper will be the cost of the extraction of the ore.

The ordinary cross-cuts from a shaft to the lode, and the levels along a lode, need not be of such large dimensions as those given for the adit, but little is gained by contracting the size of these.

In the cross-cuts the strata will usually be solid enough to form the roof; but the driving of the ordinary levels along a lode is only the preliminary operation to the cutting of the lode above the level down. When this is done, the top of the level will have to be made strong enough to bear the 'deads,' or rubbish thrown down from the working of the lode above, or, if all the lode is taken down, to secure the roadway from stones falling from the working face. This has to be done by timbering, in the following ways, or variations of the same, as special circumstances may indicate: if the workings are narrow, as in fig. 124; or, if they are too wide for a single stretcher, the full length, as in fig. 125.

The timbers should be from 7 to 9 inches in diameter, and placed a yard apart, with a good covering of thinner poles.

Sometimes the roof timber is taken right across a lode to a great width, being supported on the heading side of the level by strong uprights. In the Botallack Mine, where the lode is 22 feet wide, massive timbers of from 16 to 20 inches square form the roof, and these are often placed double, the heading side of the level being filled, as in fig. 125, with rubbish.

Winzes.—These are small shafts sunk at intervals from one level to another, partly for ventilation, hence the derivation of the name 'winds,' and partly for greater facility in working

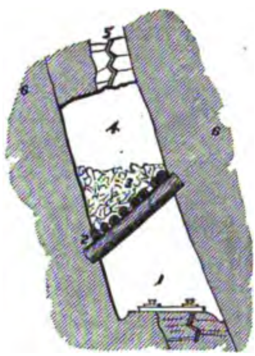


FIG. 124.—TIMBERING OF LEVEL IN NARROW WORKINGS.

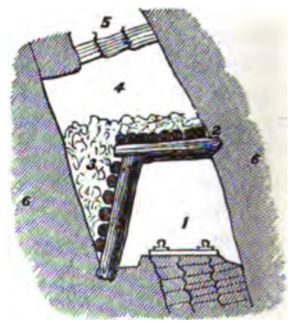


FIG. 125.—TIMBERING OF LEVEL IN WIDE WORKINGS.

Roadway. 2, Roof timbers. 3, Rubbish. 4, Working space. 5, Lode. 6, Strata a part of which by the side of the lode has to be taken down, and forms rubbish, 3.

the stopes. These may be placed the same distance apart as the levels, or a greater or less distance, as the mine may require.

The preliminary sinkings on a lode in order to prove it, referred to in the last chapter, should be arranged so as to form winzes as far as they go.

Stopes.—The working faces on a lode are called 'stopes' or steps. They are of two kinds, underhand and overhand. Underhand stopes may be compared to a man working on a flight of stone steps, and cutting away step by step, and overhand stopes to the way in which a man may stand, say on the

cellar steps, and cut down the flight of steps over his head. Up to the last century, underhand stoping alone was practised in this country, when the overhand system was introduced from Germany, where it had been in use for some time. Fig. 126 will afford an idea of overhand stoping.

When the ore has been extracted out of a large space of a lode, the walls or sides of the latter have to be supported. If enough of rubbish is not left from the working of the lode to do this, it must be accomplished by timbering, and this has often to be of a very substantial and elaborate nature, like a huge lattice or panel work. If the lode be very wide, like that of the Van, or the Great Comstock, or the vast ore chambers of Ruby Hill, scarcely any amount of timbering will bear the

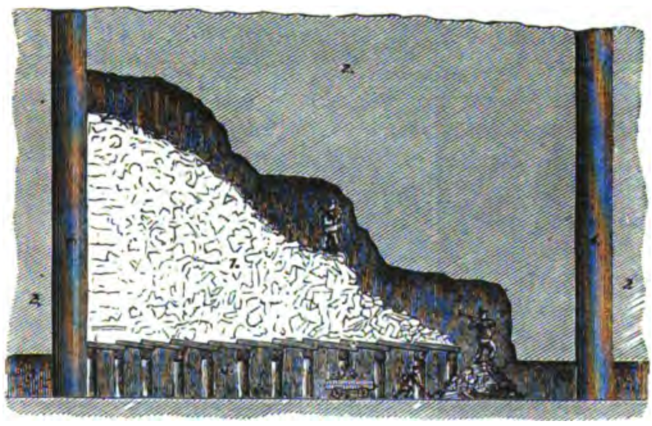


Fig. 126.—Stopes in a Mine.
1, Rubbish. 2, Unworked portion of lode. 3 3, Levels. 4 4, Winzes.

strain and pressure caused by the caving in of the surrounding rocks. The plan is therefore adopted of taking rubbish from the surface, where it may be easily and cheaply excavated, into the mine, and filling up with it the spaces from which the ore has been extracted.

In ironstone mining in the seams lying in the Coal-measures,

about three tons of material have to be removed for one ton of ironstone. The workings are usually gently sloping, and the rubbish is thrown back to form a goaf, or gob, as shown in fig. 127, which represents long wall workings in the clayband ironstone of Warwickshire.

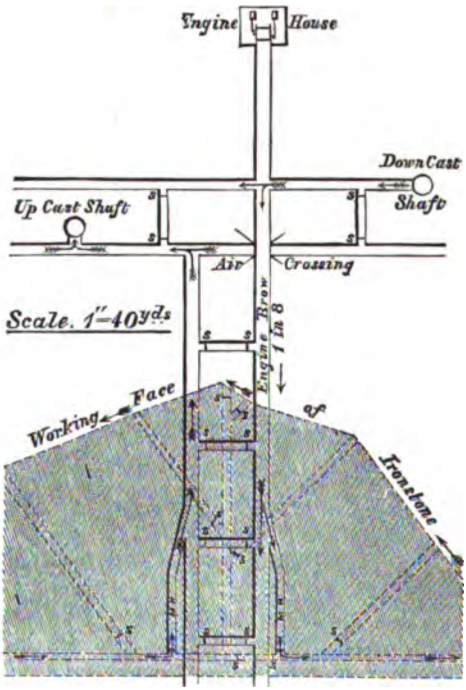


FIG. 127.—PLAN OF WORKINGS IN THE 'CLAYBAND' IRONSTONE, WARWICKSHIRE.

s, Air stoppings. Continuous lines, Fast roads in coal. Dotted lines, Ironstone workings. M H, Measure heads, or roads up from coal to ironstone. Arrows show the course of the air. Dotted portion, Worked portion of ironstone or goaf.

Fig. 128 represents a common method of working the Cleveland ironstone bed by the pillar and stall system. After roads have been formed and ventilation secured, a solid square of the bed is attached, as shown at 4. The process goes on until ventilation is obtained in the stall by opening

through and taking away part of the pillars, as in 5; until all excepting the side supports are left, as in 6. As a part of the mine becomes exhausted, the pillars are removed and the ground allowed to fall in behind the miners. But a good deal

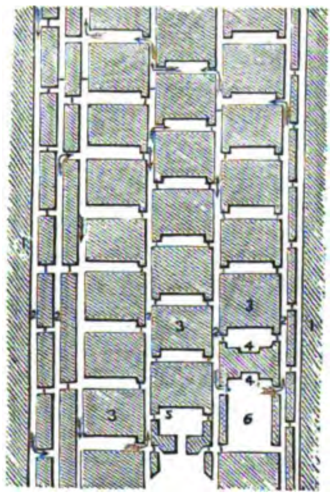


FIG. 128.—PILLAR AND STALL WORKINGS IN CLEVELAND IRONSTONE BED.

1, Goaf. 2, Roads. 3, Unworked portions of the ironstone. 4, 5, Partially-worked stalls. 6, Stall worked out. Arrows show direction of ventilation.

of timber is necessarily used in the temporary support of the roof as the workings proceed.

CHAPTER XXXIV.

ON THE WORKING OF METALLIFEROUS MINES—Continued.

Timber—Ventilation—Temperature—Fans—Old Methods of Breaking Rocks down—Drilling—Single Hand—Double Hand—Underhand—Rock Drilling Machines—History—Classes of Drills—Principles of Construction—Detailed Construction—Air Compressors—Receivers Pipes—Hand Boring Machines—Jordan's—Victor's—Faber's.

TIMBER.—It will be inferred that a large quantity of timber must be used at a metalliferous mine; and for the most part this has to be of larger dimensions than the timber used at collieries.

In newly settled countries, like the Western States of North America, the existence of 'lumber,' as the wood of the country is called in the neighbourhood of a mining camp, is of great importance. In such countries, too, the miner is glad to take any kind of timber that comes to his hand. In older settled countries, as in the mining districts of Germany and of this country, a little power of selection may be exercised.

Welsh miners like oak, and, for its strength, its durability, and its power of resisting decay in moist, confined places, it cannot be excelled, if it can be got of sufficient length and strength. Next comes larch, which, from its straightness and durability, is a very useful wood. Then follows pine, fir, and deal. Beech and birch, too, where there is plenty of ventilation; but they soon decay in a damp, confined atmosphere. Ash is tough, but too flexible for timbering the interior of mines. Alder, ebon, maple, poplar, and willow are all more or

less unsuitable. Of course timber is best if it has been felled at the proper season of the year, and if it is used dry. Various chemical preparations have been used for coating and saturating it with a view to its preservation; but these all seem now to be merging into the plan of creosoting, which answers very well.

Ventilation.—Metalliferous mines are not troubled with such explosive and actively dangerous gases as coal mines are; happily, therefore, they are free from those sudden outbursts of inflammable gas which unfortunately are so frequently fatally destructive to a dreadful extent at collieries.

Still, there are the facts that the air in a mine is nearly stationary; that by being breathed by a number of men it loses its vital properties; that it is poisoned to some extent by noisome exhalations; that it becomes charged with the fumes of explosives; and that there are occasionally outbursts of hydrogen gas where saline water falls on blende ore. Added to these considerations, there is also the natural increase in the temperature of the earth downwards, towards its centre.

Concerning this last remark, I may here notice incidentally, that, from observations made by Mr. Henwood in Cornwall, Professor J. Phillips in the North of England, Mr. Bryham in Lancashire, and Professor Reich in Saxony, as well as from the results obtained by other observers, the temperature of the earth increases downwards at a rate varying from 1 degree Fahr. for every 45 feet in depth to 1 degree Fahr. for every 76 feet in depth. It may be taken as the average result that the rate of the increase of heat is 1 degree Fahr. for every 65 feet in depth.

Ventilation is needed very early in the progress of a mine, before the first level is taken in very far, or the first shaft sunk very deep. In figs. 122 and 123 an airway is shown running under the roadway of the level, which is a good arrangement.

Many mechanical contrivances have been used in different countries and at different times for carrying fresh air into mines, but they seem likely now to be superseded by the simple circular fan, of which many varieties are made by mechanical

engineers. I have found a fan 2 feet 6 inches in diameter, driven by a donkey engine, or by a six or eight feet water wheel, suffice for the preliminary stages of a mine. The air may be sent into confined places within a mine by means of a small fan placed where the air is pure, and turned at intervals by a boy.

Ordinarily, in shallow mines, when two shafts have been sunk, or when the air entering a mine and coursing through its workings can pass out through an upper opening, the ventilation will be sufficient. If, however, many men are employed, if blasting be frequent, or if the mine be deep, the ventilation must be aided by mechanical means. Nothing can be better for this purpose than fans, which are now made of all sizes up to 40 or 50 feet in diameter, and which may be used to exhaust the foul air in a mine, so that its place may be occupied by fresh air rushing down the shafts, or by sending into the mine a volume of fresh air, which shall expel the foul, and keep the mine sweet and clear.

Where rock boring machines like those to be next described are used and worked by air, the proper ventilation of the mine will be accomplished without the use of any other means.

Boring or Drilling.—Rock Drilling Machines.—Of course, in the vast majority of instances, the lode and the enclosing strata are too hard and compact to be broken down by pick, or by the hammer and gad, or wedge. In the early days of mining, the rock was heated by lighting huge fires close up to it, and then, by throwing cold water over the heated surface, or by natural quick contraction, the rock was broken down. Quaint illustrations of this process are given in Agricola's old book on mining. This practice lingered until very lately, if it does not continue still, in some of the mines of the Hartz, in Germany.

The invention of gunpowder afforded a more effectual method of breaking down solid rock; but for the insertion of the explosive holes had, of course, to be made. The making of these holes was and is known as boring or drilling. This operation had to be performed by manual labour, with iron bars

tipped with steel, and more recently by steel borers, or drills themselves. These are of various lengths, and are about one inch diameter. Hand drilling is called 'single-handed' when one man holds a drill with one hand and strikes it with a hammer weighing about 4 lbs. with the other. It is 'double-handed' when one man holds and turns the drill, while another man strikes it with a heavy hammer weighing about 10 or 12 lbs. Or, if the work lie under the miner's feet he may drill a hole by lifting up a heavy drill and letting it fall. The usual rate of drilling by these means is one foot per hour. It is a slow, laborious process, and we do not wonder that attention was very early directed to the finding out of some means whereby, with the aid of mechanical means, manual labour might do more work, or by the application of other motive power, a better result might be attained, as a greater number of heavier blows were more quickly struck.

Rock Drilling Machines.[1]—It is said that attempts in this direction were made in Cornwall during the last 150 years. In 1812 Richard Trevethick, whose inventions have been the precursors of many useful appliances, invented a rotary machine for boring, which, with a weight of 500 lbs. placed over the drill, bored 1½-inch holes in Plymouth limestone, at the rate of one inch per minute. In 1838 two Americans, J. M. and J. N. Singer, used a large drop-drill on a portion of the Illinois Canal, about 30 miles below Chicago. The invention was patented in 1839, and about a dozen machines were put in use. In 1844 Mr. Brunton, known in this country in connection with furnaces, invented a wind-hammer for boring holes and ventilating the working face of mines. In 1853 William Pidding invented a hammer, fitted on a frame, to be worked backwards and forwards

[1] See Darlington on 'Rock Boring,' *Mining Journal*, August 4, 1877, *et seq.*; Darlington, 'Lecture on Rock-Boring Machinery,' *ibid.* December 14, 1878; Raymond, *Statistics of Mining West of the Rocky Mountains*, Washington, 1870; Leslie, *Observations on Machine Rock-Boring*, E. & F. N. Spon; Schram, *The Application of Machine Power to Rock Drilling*, G. H. Hill, Westminster Road, 1878; also the catalogues and circulars of the various makers as advertised in the Mining and Engineering papers.

by steam power, for the purpose of making holes in the end of a level. About the same time Schumann invented a machine, which largely anticipates the present rock drilling machines, for working the Freiberg mines, and a neat model of this machine is preserved in the museum of the School of Mines at Freiberg.

In January 1855, Mr. Fontainmoreau applied for a patent in England for an improved machine for boring rocks, by the use of compressed air in the cylinder for giving the blow to the drill. The invention comprised arrangements of valves for getting the air into the compressor, and an arrangement also for giving a rotary and forward motion to the drill. In August 1855, Mr. Bartlett patented a similar invention, and his machine was tried in the driving of the Mont Cenis tunnel. In 1861 M. Sommeiller, having made substantial improvements, started his machines successfully in the driving of the same tunnel. Sommeiller's machines may have the credit of being the first that were successfully and continuously used underground, and driven by compressed air. From that time until now many improvements and alterations have been made, of which I select the following:

In 1862 Edward Crease, who had been experimenting some time previously, patented a boring machine, which was afterwards used at the Clogau Gold Mine, North Wales. Its rate of boring was 1½ inch a minute. In 1866 Jordan and Darlington devised plans for turning the boring tool, and for giving a forward movement to it. In 1870 Osterkamp made a machine portable enough to be held by a man when it was doing its work; but the recoil was found to be too great, and a carriage or frame had to be adopted. The inventions now became very numerous, including the Beaumont, the Burleigh, McKean, and others; but it will be readily understood how the latest improvements are new applications of the principles embodied in the first attempts.

Rock drilling machines may be grouped into two great classes. First, those that bore by constant pressure and rotation; and, secondly, those that bore by percussion, combined with a rotary movement.

The typical example of the first group is the Diamond Rock Boring Machine, constructed from the patents of Messrs. Beaumont and Appleby. The principle of this machine is a rapidly rotating hollow shaft, on the bottom or boring end of which are fixed a number of diamonds. The machine is usually worked by steam, and its speciality is that it brings up, every time the rods are changed, solid cores of the strata passed through.

The machine is, therefore, specially adapted for prospecting, for which purpose it has been largely used, as well as for working in larger tunnels. I believe the inventors have more recently adapted it for working in the more restricted spaces of mines.

The second group may be subdivided into the following lesser groups :

1. The Direct Acting system, including Cederblom's, Darlington's, Osterkamp's, Schram's, and Reynolds' machines.

2. The Duplex system, comprising the machines of Sommeiller and Ferroux.

3. The Lever system, in which are included the Barrow, Brydon, Burleigh, Cranston, Davidson's, Dunn's, Eclipse, Ingersoll, McKean, Schumann, and Warrington drills, with some others.

4. The Ram system, comprising the machines made by Schwarzkopf and by Warsop.

The principle upon which the whole of these percussive drills act is that of the steam cylinder and piston of an ordinary steam engine. The piston is moved rapidly backwards and forwards by compressed air (usually) or steam, as the case may be, and in doing this strikes the blow upon the rock by means of a chisel or drill, which is attached to the piston-rod. Care is taken, in regulating the supply of the air or steam into the cylinder, that a portion of the inflow shall form a cushion that prevents the piston striking against the cylinder.

The variations in the different patents and inventions consist of special arrangements by which the chief end is accomplished, as well as for turning the drill around as it works, and in lengthening the machine, or so altering its position, as to adapt the blows to the ever-increasing depth of the hole.

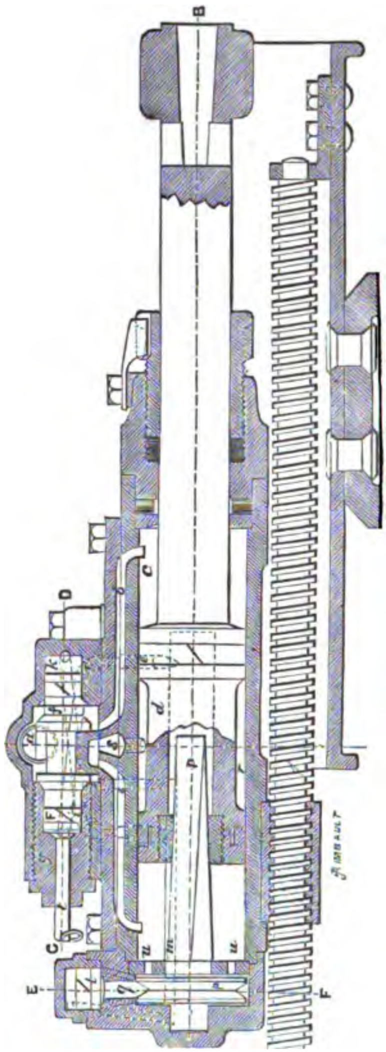


FIG. 129.—MECHANISM OF SCHRAM'S ROCK DRILLING MACHINE.

This being the principle on which the whole of the drills act, and these the objects of the various arrangements of detail, I may, without expressing a preference for any one of the best known drills, illustrate the mechanism of them by means of Mr. R. Schram's detailed figure (fig. 129) of his rock drilling machine, and by Mr. Schram's explanation of the same.

'Schram's machine consists of the following moving parts: *i.* the main piston; *ii.* the slide piston and slide; *iii.*, the rotating movement with its piston. The accompanying fig. 129 shows a longitudinal section of the machine.

'When the piston *d* is in the position shown in fig. 129, air,[1] on the cock being opened, enters the cylinder *c* through the port *b*, and pressing on the lower end of the piston *d*, forces it backwards, causing the backward stroke. As soon as the piston *d* has

[1] The machine can be worked either by compressed air or by steam.

passed the port *e*, the air rushes through that port into the small cylinder *g* (in the slide box). At this moment, when the air presses upon the upper end of the slide piston *f*, the cylinder *k*, in the opposite end of the slide box, is in communication with the outlet *s* through the port *i*, and the circular hollow in the piston rod *r*; consequently the slide piston with the slide is moved downwards, so that the passage *h* is opened for the admission of air from the slide box, whilst the lower end of the cylinder through the port *b* now communicates with the outlet *s*. The air now entering the cylinder c^1 through the opened port *h*, presses on the upper end of the piston, forcing it forward, and thus causing the drill, carried in a socket at the extremity of the piston rod, to strike with the impetus of its own weight and all the power of the compressed air against the rock. As soon as the piston *d* has passed the port *i*, air enters through it into the cylinder *k*. At this moment the cylinder *g* communicates with the outlet *s* through the port *e* and the circular hollow *r* in the piston rod, and the slide piston with the slide is moved back into the same position. Meanwhile the piston *d* has completed its stroke; the cylinder c^1 is, through the passage *h*, in communication with the outlet *s*; and compressed air again rushing through the re-opened passage *b*, causes the action just described to be repeated so long as the supply of motive power is kept up.

'It is an important feature in this machine that the slide rod *f* is made in the form of a double spindle valve; by this method of construction it remains in position, without any recoil, until the piston *d* has made the greater part of its stroke.

'As in some varieties of rock it happens that the drill often sticks fast, there is a reversing rod *t* to suddenly reverse the slide, and thus pull the drill out of the hole.

'With careless workmen it would frequently happen that the piston would strike against the lower cylinder cover, therefore there is an air cushion at the lower end of the cylinder. In addition to this there are an iron ring and an india-rubber washer (exchanged for one of wrought iron when steam is used), with the object of moderating the violence of the shock such blows, inadvertently permitted, would cause.

'In order that the hole drilled be perfectly round, it is necessary that the cutting tool should partially rotate at each backward stroke, so that its cutting edge shall every time strike the rock in a fresh place; but in order not to lose any power, it must always make its forward stroke without rotating. For this purpose a twisted bar *o* is employed, connected with a grooved disc *p*, and a brake *q* acted upon by a small piston *l*. Communicating from the slide box with the cylinder *n* is a small port *m*, by means of which the compressed air exerts a constant pressure upon the upper end of the piston *l*. When the main piston *d* makes its backward stroke, the cylinder c^1 is in communication with the outlet, and consequently there is no pressure on the lower end of the piston *l*. The constant pressure on the upper end of this piston, therefore, now presses it upon the brake *q*, which presses upon the disc *p*, preventing it from turning, and thus the main piston *d* is forced to partially rotate round the twisted bar *o* secured to the disc. But when the main piston makes its forward stroke, and steam or compressed air fills the cylinder c^1, the motive fluid enters through the small ports *u u*, and presses on the lower end of the piston *l*, thus counterbalancing the constant pressure on the upper end. There being now no pressure on the brake *q*, the disc *p* is free to rotate, and the piston *d* makes its forward stroke without rotating, partially turning the disc as it proceeds by means of the twisted bar *o*.'

The machines used underground are worked by means of air, which on the surface is compressed to several times less its own bulk, and equal to a pressure of from 60 to 90 lbs. to the inch. The air is stored in a receiver, from which it is conveyed underground to the drill by means of wrought or cast iron pipes, of sizes suitable to the number of drills worked, pipes 1½ inch diameter being equal to the supply of one drill, with which it may be connected by a strong flexible hose, as shown in fig. 130, which represents an Ingersoll drill at work in a mine. The compressors are as various as are the drills, but the object to be attained is the same, whatever shape is adopted or arrangement of valves is used. About one third of the power

derived from the compression is lost in the transit, and this loss must always be taken into account in providing the amount of air required.

The power by which the air is compressed on the surface is generally steam. Ordinarily 50 lbs. pressure of steam will obtain 90 lbs. pressure of air in the receiver, and it is estimated that a boiler of 10-horse power is equal to driving four or five drills. The amount of heat generated in the effort to compress air is very great, and the compressor has to be kept cool by water chambers, with which it is provided.

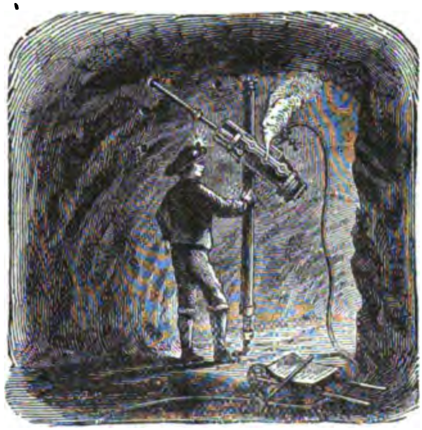


FIG. 130.—THE INGERSOLL ROCK-DRILL IN WORK.

The same results may be obtained by the use of water wheels, or turbines, of sufficient capacity and strength.

The appliances on which the drill is fixed are very varied, from a movable frame on wheels to a simple stretcher screwed horizontally or vertically across a level, as shown in fig. 130.

Drilling by machinery is as yet in its infancy, and it is perhaps too soon to judge of its cost in comparison with hand labour. Miners will have to grow up accustomed to the handling and working of the machines. So far as appears from a comparison of costs which I have made, I think we may at

present depend upon getting the work done at three-fourths of the cost of hand drilling; while, as the rate of progress is eight times as fast, a great saving will be effected in costs of management and other fixed expenses. We have not, however, as yet attained the minimum of cost in machine drilling operations.

The specialities of the different drills I have named will be

FIG. 131.—JORDAN'S HAND-POWER ROCK-DRILL IN WORK.

best learned from the descriptive and illustrated circulars issued by their makers. They are all doing good in various parts of the world in mining and engineering operations, and it is only by a comparison of their respective merits that the reader can judge of their adaptation to any particular kind of work.

In the North Wales and Shropshire mining districts, where I write, an adaptation of Beaumont's drill is doing good work at the Halkyn Deep Level. Darlington's simple and effective machine and compressor is working well at the Minera Lead Mine. At the New Crickheath Lead Mine an Ingersoll drill is carrying a level forward at the rate of 12 yards a week; and

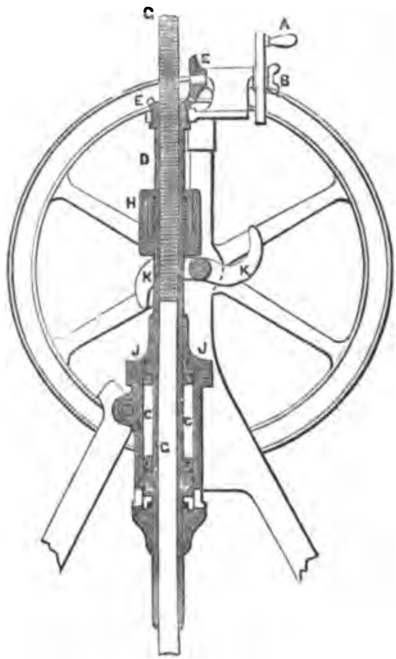


FIG. 132.—MECHANISM OF JORDAN'S HAND-POWER ROCK-DRILL.

at the Roman Gravels Lead Mine an Eclipse drill is working satisfactorily in one of the deep levels.

The cost of steam engine, compressor, receiver, pipes, and drill amounts to a large sum, which, while its expenditure is not felt in an established and successful mine, or in a mine starting with a good capital, is a good deal to expend in the

ordinary class of mining operations. Attempts have therefore been made to construct a machine that shall utilise and intensify the strength and labour of two or three men, by the aid of mechanical appliances. One of these is the 'Hand Power Rock Drill' of Messrs. Jordan, Son, & Meihe. This drill is shown at work in fig. 131, and the construction and working of the machine will be understood by a reference to the section of it given in fig. 132. C is an air-tight cylinder in which the piston L works by being forced up and down by the action of the fly-wheels upon the cams K K; when the piston is raised, the air above it in the cylinder is compressed into much less than its ordinary bulk. This compression forces the piston downwards as soon as it is free, and thus strikes the blow. G is the drill bar fixed within the piston, and by a simple arrangement of screws and bevil wheels at D, E, and B, this bar, every time it strikes the rock, is partly turned around, and so lengthened to follow the deepening hole, besides doing its work more effectively.

About 150 blows of from 130 to 160 lbs. each can be struck per minute, the progress made being from 40 to 70 inches per hour, according to the nature of the rock, or quite four times the ordinary rate of progress.

Another hand drill is the Victor, in which the drilling tool is lifted up by cams, as in Jordan's, and is forced back by a spiral spring. A more recent invention by Faber, of Barmen, Prussia, causes the spring to be pulled up as the drill is lifted by the cams, the spring when released quickly pulling the drill down again, and so giving the blow.

We still want a cheaper and more portable machine for working in stopes. It need not do its work so quickly, and yet save a great deal of manual labour and much cost.

CHAPTER XXXV.

ON THE WORKING OF METALLIFEROUS MINES—Continued.

Explosives—Gunpowder—Compositions of Various Kinds—Principle of Explosion from Nitro-glycerine—Dynamite—Lithofracteur—Tonite—Gun-cotton—Patent Gunpowder—Explosion by Detonators—Saving that could be effected often prevented by Miners—Plan adopted in American Mines—Danger—Firing by means of Electricity.

EXPLOSIVES.—*Gunpowder.*—The actual discovery of gunpowder is lost in obscurity. The Chinese claim to have used it long before it was known in Western Europe, where its discovery is assigned to Berthold Schwartz. An explosive powder was known in this country and used for heavy cannon in the eleventh century; but it was not until the thirteenth century that its composition became more accurately defined and its power understood. It was not until three centuries later that powder was used in mines as an explosive, when Martin Weigal first proposed its use in the mines of Freiberg in the year 1613; but it was not before 1630 that its use became general in the mines of the Hartz and Erzgebirge. Forty years later, or about 1670, it was first used in England at the Ecton mines, on the borders of Stafford and Derby, when it was used not so much to break down the rock underground as to split up great blocks of stone which had been brought down by the old methods of fire and wedges. Early in the eighteenth century it was introduced into the mines of Western Cornwall by two men named Bell and Case, who came from the Eastern coast, and who had learned the secret from the Germans. Since that date its use has become almost universal in mines,

and until very recently it was the only explosive ordinarily used.

The composition of ordinary gunpowder as made in different countries is as follows:

	England	France	Germany	China
Nitre	75·0	75·0	75·0	75·6
Charcoal	15	12·5	13·5	14·4
Sulphur	10	12·5	11·5	10·0
	100·0	100·0	100·0	100·0

The power of powder, and indeed of all the explosives to be described to rend asunder the substances in which they are enclosed, depends upon the setting free the moment they are ignited of those enclosed gases, which are increased many times the bulk in which they lay in the constituent parts of the powder. The more instantaneous the ignition of the whole mass the greater the rending force; hence the superiority of explosion by detonators over simple ignition. M. Berthold, a French chemist, estimates the relative explosive force of the different kinds of powder, and of substances which form the base of other explosive compounds, as follows:

Blasting powder	88
Artillery powder	137
Powder with a base of nitrate of soda	190
Powder with a base of chlorate of potash	309
Gun-cotton	472
Gun-cotton with chlorate of potash	680
Nitro-glycerine	939

Berthollet, a French experimenter, endeavoured, towards the close of the last century, to increase the force of blasting powder by the use of chlorate of potash as a base, but the destruction of his works, workmen, and part of his family, with the miraculous escape of himself, by an explosion caused by his striking his cane on a grain of powder lying on the floor, put a stop to his experiments.

Since that time various experiments have been made in the

same direction, and compounds have been introduced as safe and powerful, but the extreme danger attending the manufacture, carriage, and storage of such compounds has hitherto prevented these chloratic powders from coming into general use.

There are variations of black blasting powder now in use. For example, Messrs. Curtis and Harvey make a very strong and safe explosive. There is also the powder called *pudrolithe*, whose properties are at present, however, little known.

Nitro-glycerine.—The discovery of nitro-glycerine by M. Sobrero in 1847 has led to the manufacture of a new group of mining explosives of the most wonderful power. Nitro-glycerine itself is formed by the action of nitric and sulphuric acid upon glycerine. This is a thick, syruplike-looking liquid, with a sweet taste, that is obtained chiefly from the fatty substances used in the manufacture of soap and candles. When, by the action of the acids named, it becomes nitro-glycerine it is an oily liquid like olive-oil, with a sweet and rather aromatic taste, but without smell. It is poisonous when taken into the stomach or absorbed through the pores of the skin. Its vapours when exploded cause violent headache. It explodes at a heat of about 360° with great force, which it also does if struck with a hammer. Even the blows made in unpacking the wooden cases in which tins containing it have been packed have caused terrible explosions.

In exploding, nitro-glycerine gives out twice the amount of heat generated by gunpowder. It has therefore been calculated that if a volume of powder gives 200 volumes of cold gas expanded by heat four times to 800 volumes, a volume of nitro-glycerine gives 1,300 volumes of cold gas, which expanded by heat eight times produces 10,400 volumes. Its explosive power is consequently about thirteen times that of powder.

Practically, it has been found that the use of nitro-glycerine in this unmixed and liquid form was attended with such extreme danger that it could neither be used, carried, or stored with any degree of safety. The attention of scientific men was,

therefore, long directed to the devising of some means whereby it might be safer to handle and use, without losing much of its explosive force.

Dynamite.—As one of the first outcomes of these efforts was the invention and manufacture of this explosive by Mr. Alfred Nobel in 1867. Dynamite, which is also known and extensively used in America as Giant Powder, is stated to be a mixture of nitro-glycerine with an infusorial earth, that consists principally of the minute porous silicious shells of the Diatomaceæ.

It is of a greyish brown colour, and it freezes or congeals at a temperature of 43° Fahr. It is claimed for it that it is as safe as ordinary powder in the handling; that small portions of it may be exploded by a blow; but packages containing it may be freely handled. It must be kept dry, but it may be used in wet ground. An American mining captain thus sums up the advantages of its use as compared with ordinary powder[1]:

'1st. The amount of work which can be performed in a given space in a mine is nearly double.

'2nd. The consumption of steel is about one half.

'3rd. The consumption of hammers is about one half.

'4th. The consumption of candles is about one half.

'5th. The width of drifts or stopes is only about one half, requiring so much less material to be hoisted from the mine.

'6th. The mining timbers required are much shorter.

'7th. The ore raised from the mine is broken by the force of the powder, so as to require less spalling for the mill.

'8th. The progress of the work in the mine is expedited at least 40 per cent., and in wet mines the progress is increased fully fifty per cent., if not more.'

The yearly consumption of dynamite is now very large in all mining countries.

Two variations of dynamite have recently been introduced. First, its explosive power has been increased by issuing it in a

[1] Raymond, *Statistics of Mining West of the Rocky Mountains.*

more liquid state; and, secondly, its safety has been increased at the cost of some reduction in its explosive force, by the addition of camphor.

Lithofracteur.—This is the name given to another very valuable adaptation of nitro-glycerine, as invented and patented by Messrs. Krebs Bros., of Cologne, who have agents in the chief mining districts of this country. As far as may be surmised, this explosive differs from dynamite in the use of a less proportion of nitro-glycerine, and the use, as absorbents, of substances which are explosives themselves, instead of a non-explosive, as infusorial earth. The result is said to be more powerful than that of dynamite; the use of it to be quite as safe; and the fumes, when exploded, less noxious than those of dynamite, from the fact that the whole of the nitro-glycerine in the compound is consumed. I do not pretend to decide these points, but that it is a most valuable and powerful explosive I have no doubt, as the following examples of work done by it, and witnessed by myself, will show:

The bed of mineral to be won was about one foot wide. It was underlain by several beds of hard limestone, which had to be blown down to a width of about 3 feet before the mineral bed could be blown down. A one-inch hole was drilled in the solid limestone, in the face of one of the stopes. The hole was placed 4 feet 6 inches above the underside of the stope, and it penetrated the limestone 3 feet. This hole was charged with 12 ounces of lithofracteur. The whole mass of the limestone, 3 feet wide, 4 feet 6 inches deep at the face, and from the end of the hole irregularly downwards to a total distance of 6 feet 6 inches, was detached and broken, so that it was worked down with a pick. Another charge of 12 ounces brought down bodily a mass of the limestone on the face of a stope, 4 feet long, 3 feet wide, and 3 feet deep. Two other charges gave similar results.

Tonite, or *Cotton Powder*, is another powerful explosive. It seems to be a mixture of nitric acid, with cellulose substances, cotton woody fibre, hemp paper, and the like. It is held by its makers to be the 'safest, cheapest, and strongest of all explo-

sives,' which is, of course, saying a good deal. In experiments that were made at Messrs. Clayton and Speight's collieries, near Leeds, in June 1877, Mr. Dineen explained that tonite is of a different nature to dynamite or gun-cotton. It contains no glycerine, and it will not explode except by means of a detonator specially prepared.

Gun-cotton, closely allied, however, to tonite, is the older explosive gun-cotton, and also the explosive recently manufactured by the Patent Gunpowder Company, at their works in Glyn Ceiriog, North Wales, from woody fibres.

Improvements have lately been made whereby the *cellulose*, by being soaked previously in sulphuric acid, is reduced to a fine impalpable powder, in which it is in the best state possible for the absorption of explosive liquids, and the improvements will affect all those explosive compounds in which cellulose matter is used.

Besides the compounds I have described there are a great number of adaptations of nitro-glycerine and nitric acid, with cellulose and other matters. The science of explosives is probably yet in its infancy, and possibly we may hear before long of explosives safer and stronger than any yet discovered. Happily the reversal of the judgment given by Mr. Justice Fry in June 1877, which practically gave to Nobel's Explosive Company the exclusive control over nitro-glycerine compounds, leaves the field of discovery and manufacture open, which otherwise it would not have been.[1]

Detonators.—The whole of the nitric acid and nitro-glycerine preparations just described require to be exploded by a detonator, which is usually a cap partly filled with fulminating powder, which, when the fuze has been fixed in it, is placed in a small cartridge, probably itself more explosive than the bulk of the material. The fuze is lighted in the ordinary way.

[1] Since the above has been in type, Mr. Justice Fry's judgment of 1877 has been confirmed; consequently, lithofracteur cannot now be sold or used in this country. Practically, and apart from the legal aspects of the case, this is a misfortune to mining, and it is to be feared that improvements in nitro-glycerine explosives will be impossible for some years to come.

The great danger to the miners lies in unexploded charges, and here the greatest care must be taken. The Government rules are very stringent, and should be implicitly obeyed. The instructions given by the makers of the different explosives should also be closely adhered to.

There is no doubt that the explosives just described are as safe as ordinary powder, and that they will, if the holes are placed with judgment, do several times the work of ordinary blasting powder. But we want a new generation of miners before these explosives will perform all the work they are capable of. It is found, I think, that the men will, if not watched, persist in placing the holes just in the way they did before, and bring no more rock down at a charge than they did with the old powder. They are more intent on saving the powder than of bringing down plenty of ground.

To obviate this, the plan has been adopted in some American mines of appointing one or more intelligent firemen, whose work it is to direct where the holes are to be drilled, and to fire the shots. The men are paid so much per foot for drilling. When the holes are deep enough the depth of them is measured, and the drillers are removed to another part of the mine. The fireman then charges the holes and fires the fuze. Then the fillers come and remove the stuff, and the process is repeated.

Firing by Electricity.—Efforts have been made, since the days of Franklin in 1757, to supersede the ordinary method of igniting explosives by means of fuze, by the explosion of such charges by means of electricity.

For some time past our Government, as well as others, have, under the advice and by the help principally of Mr. Bell, largely adopted this method in large quarry operations, and in the firing of trains or torpedo-like machines.

Recent attempts in the application of the system to quarrying have also been successful; and the operation is valuable in the sinking of shafts, because it can be performed on the surface after the miners have come out of the pit.

The principle is simple. Instead of fuze double wires prepared for the purpose are inserted in the explosive charge,

When a number of charges are to be exploded, one wire from one hole is securely attached to one wire in the next hole and so on, the circuit being made complete through all the charges. The electricity may be excited by an ordinary electrical machine, although there are now some specially prepared for the purpose. When a sufficient quantity is stored the circuit is completed to the machine, and the whole of the shots are simultaneously fired.

Good illustrations of the method are given in a pamphlet on Barnhardt's Electrical Firing Machine, which is issued by Mr. John Darlington, of 2 Coleman Street Buildings, London, E.C.

Applied to quarries, open workings, large shafts, and workings where there is plenty of room, the method will be found advantageous in many respects. But the care required is so great, the risks of failure numerous, and success is so dependent upon delicate and intelligent manipulation, that I fear it will be some time before we have miners sufficiently intelligent, skilful, and patient to manage the process.

CHAPTER XXXVI.

ON THE WORKING OF METALLIFEROUS MINES—Continued.

Drainage and Pumping—Ancient Methods—Barrels—Hand Whims—Horse Whims—Water Wheels—Newcomen's Engine—Watt's Engine—Saving effected in Fuel—Register of Duty, 1812, 1844, 1878—Tables of Work done—Improvements, resulting in Increase of Duty, in Boilers, Engines, Shaft Appliances—General Description of Pumping Arrangements in a Shaft—Other Pumps—Hydraulic-power, Windmills—Great Tunnels for Drainage—Blackett, Halkyn, Redruth, Kit Hill, Ernst August Rothshönbergen, Emperor Joseph, Comstock.

DRAINAGE AND PUMPING.[1]—One of the first, and usually the chief, difficulty encountered by the miner lies in the presence of water, which, finding its way from the surface through chinks and crevices of the strata, or through strata porous in itself, rapidly accumulates in underground excavations.

The difficulty increases as he passes below the adit, usually short, driven for the purpose of draining the superficial strata. The old book on mining by Agricola, already referred to, contains many illustrations of the rude contrivances employed up to his time to overcome the inflow of water. 280 years ago few mines in Cornwall were worked at a greater depth than from 30 to 40 fathoms. The drainage machinery then employed was of much the same character as that described by Agricola, for, we are told by Carew,[2] it consisted of 'pumps and wheeles

[1] John Bourne, *Treatise on the Steam Engine*, Longmans; Warrington W. Smyth, *Coal and Coal Mining*, Crosby Lockwood & Co.; S. Hughes, *Water Works, &c.*, Crosby Lockwood & Co.; Husband, 'Lecture on Pumping Machinery,' *Mining Journal*, June 22, 1878, *et. seq.*

[2] Carew, *Survey of Cornwall*, 1602.

driven by a streame, and interchangeably filling and emptying two buckets, with many such like.'[1] Towards the middle of the last century, a good deal of water was raised by hand and force pumps. For mines of shallow depth, water barrels, worked up and down the shaft by a windlass, and in mines of greater depth by a horse whim, were employed. A common device, and one still practised in the East, was the rag and chain pump, which consisted of a chain, on which was tied at intervals a bundle of rags, working up a pipe, up which the rags brought the water from the bottom to the top.

One of the deepest mines at that time was the Buller Garden Mine, and in 1778 it was 90 fathoms deep, and was unwatered by means of an engine shaft extending to the bottom. In this shaft there were two pumping 'fire-engines,' raising the water from the sump to the lower adit, a height of 67 fathoms.

Surface water was early utilised in Cornwall and elsewhere for turning large water wheels, which were made to work pumps. A wheel at Cook's Kitchen Mine, at the date just given, being 48 feet diameter. It worked tiers of pumps of 9 inches bore, divided into four lifts, and raised water 80 fathoms to the adit. Its power was calculated to be equal to a Newcomen's improved fire-engine of 47-inch cylinder. Water wheels still do good service in pumping where the water supply is ample, some of them being of great size; the drawbacks to their successful working being drought in summer, and long-continued frost in winter.

Newcomen's fire-engine, which was introduced about the year 1710, underwent many improvements up to 1780; but about that date the quantity of coal consumed by an engine of good size amounted in value to 3,000*l.* yearly.

From 1770 the improved engines of Watt gradually came into use; the terms on which the inventor let them being the payment to him of one-third the value of the coal saved over the amount consumed by the old Newcomen engines.

This was very great, for we find that at Chacewater Mine,

[1] Pryce, *Mineralogia Cornubiensis.*

the saving in the fuel consumed by three engines amounted to 7,200*l.* a year.

An ingenious mechanism had to be attached to the beam of the engines to register the number of the strokes made and the length of the strokes; a record being also kept of the consumption of coal. When Watt's patents died out, this registering of work done fell for a while into disuse; but about the year 1812 the practice of registering the duty performed by the engines and the expenditure of fuel was revived, and placed under the charge of the late Captain Lean, and the work, as far as it relates to the best engines, has up to this time been continued by his son.

The duty of an engine is the amount of work done in relation to the amount of fuel consumed. The method adopted in Cornwall has been to find out what weight of water has been lifted one foot high by the consumption of a bushel=94 lbs. of coal. Of late years the bushel has been exchanged for the hundredweight of 112 lbs. This found out, the ascertaining the weight of water lifted out of a mine of a given depth, is simple. Thus, if an engine, by the consumption of 112 lbs. of coal, lifts 60,000,000 lbs. of water 1 foot high, the amount raised out of a shaft 100 fathoms, or 600 feet deep, would be 100,000 lbs. This being the result of dividing the amount raised 1 foot high, by the depth of the pit, 600 feet.

The highest duty reached by any of Watt's engines was 24,000,000 lbs., but by frequent improvements in their construction, and in the arrangement of the pumps, the amount gradually increased, until in 1844 the average duty performed by 37 engines was 68,000,000 lbs. of water raised 1 foot high by the consumption of 112 lbs. of coal, or a consumption of 3½ lbs. of coal for every effective horse-power. In March 1878 the average duty had declined to 49,000,000 lbs. or 4½ lbs. of coal for every horse-power, or an increase of quite 25 per cent. on the cost. In June of the same year, the duty performed had increased, being as follows:

The number of pumping-engines reported for this month was 16. They consumed 2,116 tons of coal, and lifted 16·5

million tons of water 10 fathoms high. The average duty of the whole was, therefore, 52,400,000 lbs. lifted 1 foot high, by the consumption of 112 lbs. of coal. The following engines exceeded the average duty :

	Million
Dolcoath—85 in.	58·8
Mellanear—Gundry's 80 in.	56·2
West Basset—Thomas's 60 in.	55·9
West Wheal Frances—58 in.	55·3
West Tolgus—Richard's 70 in.	57·0
West Wheal Seton—Harvey's 85 in.	72·1
West Wheal Seton—Rule's 70 in.	75·4

Still there is a decline of pumping power compared with 1844, and a variety of reasons have been assigned for the falling off—such as the use of inferior coal, less carefully trained stokers, and working the engines with less expansion of steam than formerly; but perhaps the chief reason lies in the fact that the mines are, on the whole, three times their former depth, or 300 fathoms instead of 100 fathoms. The greater depth, of course, entails a greater length of pump rods, and correspondingly more friction.

The useful table on pp. 338–9, compiled by Mr. J. B. Simpson,[1] presents in a very complete form the work done by 12 different engines, together with the cost of the same.

Assuming that my readers understand the principle on which a pump acts, fig. 133 will represent the ordinary pumping arrangements in a mine shaft. Fig. 134 is a continuation of the same as in a section at right angles to 133 up to the surface.

It will be seen that the water is drawn first of all from the sump through the suction pipe 1 by means of a bucket with valves working in the barrel 4, and is forced up from thence 80 yards or so to the plunger arrangement at 6, 7, 8, and 9. From this point upwards, plungers, which consist of a solid piece of iron, 8, working in a barrel or cylinder, 9, are generally

[1] Simpson, *Transactions of North of England Institute of Mining and Mechanical Engineers* vol. xix. p. 201, *et seq.*

used in preference to the bucket and valve arrangement at 4, for the reason that the water does not by the adoption of this means need lifting. The weight of the rods 12, 13, or as much of this weight as is necessary, forces the plunger 8 down, which in its turn sends the water up the adjoining pipe, A, to the next plunger, and so on up to the adit level or other point of discharge, a valve placed near the point 10 preventing the return of the water downwards. The weight of the column of water in the pipe is thus balanced by the weight of the rods. The extra weight of the rods above what is required for this purpose being balanced by the erection of T bobs in short levels driven at convenient points in the shaft.

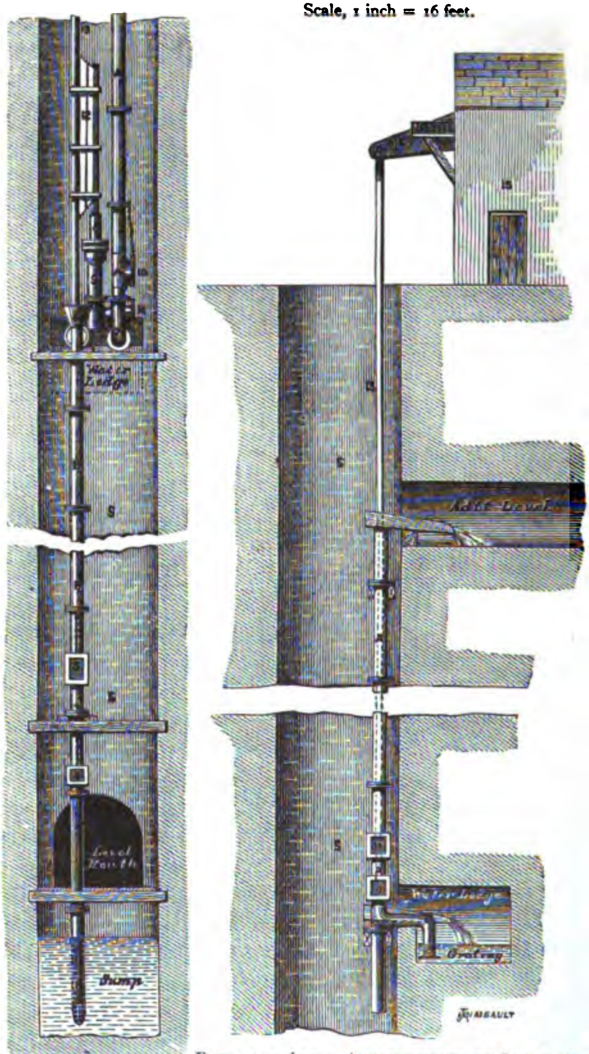
Compared with what was done sixty or seventy years ago, it will be seen that pumping-engines do now about three times the work they did then. This result has been accomplished by means of improvements (1) in the construction of boilers; (2) in improvements of the engines, particularly in the arrangements about the cylinder; and (3) by the superior mechanism of the pumping arrangements in the shaft itself. The boilers have been made stronger; Taylor's boilers, for example, being ⅝ of an inch thick and equal to 60 lbs. pressure. Then, in Cornish boilers, by the arrangement of flues running through them, a larger surface of water is exposed to the direct action of the fire. The same result is attained in tubular boilers. In the engine there is the expansion of the high-pressure steam, which is effected by cutting off the supply when the stroke is only about a quarter made. There is also the addition of an outer case to the cylinder, which, when filled with steam and cased by a covering of non-heat-conducting materials, preserves the heat of the cylinder itself. Then in the shafts great attention has been paid to the construction of the pump rods, so as to provide strength without the addition of weight or friction. The latter is also avoided by the free use of rollers, especially in inclined parts of the shafts, as well as by the nice adaptation of balance bobs; so that a great engine lifting up a vast quantity of water now does its work easily and smoothly.

Thus far the pre-eminence must be conceded to Cornish

No.	Kind of engine	Diameter of cylinder	Stroke in cylinder	Stroke in Pit	No. and description of lifts	Length of lifts, in fathoms	Diam. of plunger or barrel, in inches	Load in pit	No. of strokes per minute	No. of gallons per minute	Time of experiment, in hours	Coal consumed in 24 hours
		ins.	ft. in.	ft. in.				lbs.				tn. ct. q. lb.
	HEBBURN—											
1	Cornish Engine .	70	9 11	7 11	1 Plunger 1 Do. 1 Do. 1 Bucket	38 40 36 6	21 18·5 18·5 19	88,697	7·03	829	12	5 16 0 0
2	Boulton and Watt	63½	6 6	6 6	1 Bucket 1 Do. 1 Do. 1 Do.	42 15 27 27	11 17 12 12	35,064	12	1086	24	10 0 0 0
3	Double Beam Engine—Non-rotative condensing .	77	9 9	7 9	1 Bucket 1 Do. 1 Plunger 1 Bucket 1 Do.	30 30 33 63 4¼	20 17 28·75 14 18	125,769	5½	1474	12	18 18 2 16
4	Do., Non-condensing .	44	6 8	6 8	1 Bucket 1 Plunger	35 38	18·56 18·25	50,401	5	385	24	5 6 2 14
5	Single Beam — Non-condensing . .	48	8 0	8 0	1 Plunger 1 Bucket	32 30	21 10	34,898	3½	416	24	7 16 0 0
6	Do., Condensing	82	7 9	8 6	1 Plunger 1 Do. 1 Do. 1 Bucket	54 54 54 53	15 15 15 12	89,903	3	191	24	21 4 0 0
7	Do., Barclay's Patent .	70	8 0	9 0	1 Plunger 1 Bucket	42 14	25 14	57,988	3½	669	—	—
8	Do., with Pump at both ends—Condensing	65½	6 7	6 7	1 Bucket 1 Do.	59 46½	15·5 13·5	46,192	5½	324	24	15 18 0 0
9	Direct-Acting	52½	7 4	7 4	1 Bucket 1 Plunger	13 35½	20 20	39,565	5	495	24	4 11 0 0
10	Horizontal Rotative — Condensing .	42	6 0	5 4	1 Bucket 1 Do.	37 37	20 20	60,368	10	1450	12	5 10 0 0
11	Do., Non-condensing .	44	6 0	6 0	1 Bucket 1 Do.	45 45	21 21	80,943	4·68	837	180 dys.	9 10 0 7
12	Do., do. . .	40⅜	6 0	5	1 Bucket 1 Do.	50 50	17 17	58,940	8	785	24	13 0 0 0

Indicated pressure in cylinder	Effective h.p. of work	Indicated h.p.	Loss of power	Percentage of useful effect	lbs. per h.p. per hour on effective duty	lbs. per h.p. per hour on indicated duty	Millions of lbs. lifted 1 ft. high with 112 lbs. of coal	Gallons lifted 100 yards with a ton of coal	No. and description of boilers	Size of boilers	Cost per annum per 100 h.p. of effective duty, coal at 4s. per ton.	Cost per annum per 100 h.p. of indicated duty, coal at 4s. per ton	Time engine has worked, in years
lbs.											£	£	
22·7	149·16	184·5	35·34	80·7	3·6	2·93	61·28	407,371	3 Cornish	34 ft. by 6 ft. 9 in. tube 4 ft. 3 in.	233	230	5
11·68	81·86	87·43	5·57	93·62	11·3	10·6	19·69	131,362	2 Haystack	14 feet diam.	891	834	60
13·41	161·65	202·94	41·29	79·65	10·9	8·7	20·39	137,048	4 Common	31 ft. long, 6 ft. diam.	854	680	25
20·11	50·10	61·76	11·66	81·12	9·9	8·0	22·68	151,694	2 Cornish	30 ft. long, 6 ft. diam. tube 3 ft. 3 in.	763	631	20
11·4	29·34	35·0	5·66	83·83	24·8	20·8	9·01	59,564	2 Common Juke's patent fire-bars.	30 ft. long, 6 ft. diam.	1940	1626	20
—	69·29	—	—	—	28·5	—	7·78	51,904	4 Common	30 ft. by 6 ft.	2234	—	25
—	58·72	—	—	—	—	10 ?	—	—	Cornish	30 ft. by 6 ft. tube 3 ft. 3 in.	—	788	3
—	54·16	—	—	—	27·4	—	8·02	53,523	3 Common	30 ft. by 6 ft.	2143	—	15
26·8	43·65	64·46	20·81	67·42	9·7	6·5	22·95	151,959	2 Cornish	30 ft. long, 6 ft. diam. tube 3 ft. 3 in.	761	515	7
22·67	97·5	114·2	16·7	84·9	10·6	8·98	20·81	149 870	3 Common	30 ft. long, 6 ft. diam.	849	708	2
—	70·0	82·0	12·0	84·0	12·5	10·9	17·22	120,527	3 Cornish	34 ft. by 5 ft. 9 in. tube 3 ft. 3 in.	977	852	3
21·47	71·36	79·98	8·62	89·22	16·9	13·9	13·05	86,953	3 Common	35 ft. long, 5 ft. diam.	1329	1186	2

Scale, 1 inch = 16 feet.



FIGS. 133 and 134.—ARRANGEMENTS OF PUMPS IN A MINE SHAFT.

1, Wind bore or snow piece, suction pipe. 2, Platform and bearers across shaft at mouth of level. 3, Clack door, for convenience in raising 'clack' or valve at the bottom of the working barrel 4. 4, Working barrel. 5, Bucket door for inspecting or renewing the bucket and valves. 6, Wooden shoot for delivering water into the water lodge. 7, Suction pipe or wind bore of the plunger or forcing lift. 8, Iron plunger or ram, working through a stuffing box into the plunger case 9. 10, 11, Clack or valve doors. 12, Set-off, or junction of plunger rod and bucket pump rod. 13, Pump rods rising to junction with main working beam at 14. 14, Main working beam. 15, Engine-house. A A, Plunger-lift. B B, Bucket-lift. S S, Shaft.

engineers for getting the most work done by their pumping engines for the least money—although great results are attained in the North of England. Besides the pumps I have described there are the useful pumps of Tangye, another of Haywood, with the recent invention of Daveys, manufactured by Hathorn, of Leeds; but for deep mines and large inflows of water the old pumping arrangement must remain. Efforts may however be made to increase its power by the use of stronger boilers and more perfect engines and machinery.

Efforts are being made to utilise surface water for pumping and winding by means of hydraulic apparatus, a high thin column of water in a shaft being made to throw up a larger column a lesser height. For an interesting account of work done, chiefly in Germany, the reader may consult a paper by Mr. John Darlington, in the 'Report of the Miners' Association of Cornwall and Devon for 1874.'

Dr. Raymond[1] suggests that for high, dry, and remote districts, like those abounding along the Sierra Nevada, windmills may be used with success in mining operations; and certainly there is room for experiments in this direction. The windmills of Norfolk and Holland, particularly those of the latter country, have done good work in surface draining, and there does not seem any reason why the adaptation of this power might not be applied to the working of mine pumps and the movement of ore stamping and dressing machinery. As a matter of fact, too, windmills have been used for mining a century or two back. In 1708 they were used at several collieries in Scotland for pumping. On an old map of the Mona Copper Mine in Anglesea, dated 1785, a windmill is shown in use. At the same mine one, constructed by Captain Hughes, is now working well. Windmills were also occasionally used half a century ago at some of the Cornish mines. Not long ago one was used at a lead mine in Flintshire, for dressing the ore. Another has been in use several years at the Rosebush Slate Quarries, in Pembrokeshire; and one has just been erected by Captain Davies, at the Clogau Gold Mine, Merioneth-

[1] *Statistics of Mining West of the Rocky Mountains.*

shire. The great defect of this source of power is its intermittent action; but in some instances this is overcome by utilising the excess of power possessed at times to pump water from a lower to a higher level, where it is stored for use on calm days. At the present time attention is drawn to this question, and the mining papers have numerous references and suggestions relating to the subject.

Notwithstanding the immense power of the engines employed, varying as they do from 800 to 1,000 horse-power, it has been found practically impossible to drain some mines, especially those in limestone regions. Thus an 800 horse-power engine was found unable to unwater the Rhosesmor Lead Mine in Flintshire, and an 85-inch cylinder engine was comparatively powerless at one of the Derbyshire mines in the same formation.

Those of my readers who have seen Holywell, where a river able to work mills and manufactories rushes from underground, may form some idea of the volume of water that has often to be contended with in limestone regions. One consequence of this flow of water is that in Derbyshire it is found impossible to work the lead mines below the level of the old 'soughs,' or adit levels which have been driven, and at this moment some known productive mines are idle in Flintshire from the same cause.

These considerations, with the expense also that is entailed by pumping from deep mines, have led, where the country lies high above the sea, and the contour of the surface is favourable, to the construction, at a great cost, of long capacious district tunnels.

One of these in this country is the Blackett level, commenced by Mr. Beaumont, on his property in East Allendale, in 1850, and whose entire length is nearly seven miles. The Halkyn drainage level, which, under the superintendence of Messrs. John Taylor & Sons, is now progressing at the rate of 80 yards a month, starts from a point between Flint and Halkyn, and will extend to the neighbourhood of Mold. This will be about seven miles long, and it will drain the lead mining

region of Halkyn Mountain, including the Rhosesmor Mine just alluded to. In the mining district of Redruth, in Cornwall, there is a tunnel which, including its branches, has a length of nearly forty miles. The Kit Hill tunnel, in the same county, is another similar great work now in course of construction.

In Germany there is the Ernst August tunnel, which was begun in 1850, at a place near Gittelde, in the Duchy of Brunswick, and which extends a distance of fourteen miles to underneath the town of Clausthal in the Hartz, where it drains the mines to a depth of 1,200 feet below the church of that town.

The Rothshönberger Stollen, a tunnel near Freiberg, in the Erzgebirge, is eight miles long, and with its branches much longer; and a tunnel twenty-four miles long is in contemplation in the same district.

The mining district of Schemnitz, too, in Austro-Hungary, has a level, 'The Emperor Joseph,' more than nine miles in length. The Comstock tunnel, in Nevada, is another great work, just now completed, as far as the main level is concerned, and an idea of the magnitude of this work will be gained by a reference to figs. 39 and 40.

These great works can, however, at the most only drain down to the sea level, and if the metallic ores contained in watery strata below this level, and which hitherto have been deemed unattainable, are to be won, stronger and more effective means than any hitherto known must be conceived and adopted. Here is a field for engineering enterprise, for we must not be beaten. We are bound ultimately to win.

CHAPTER XXXVII.

ON THE DRESSING OF METALLIC ORES.

Picking and Sorting—Crushing with Hammers—Spalling—Ore-breaking Machines—Blake's, others—Stamping and Stamps—Old Cornish Stamps—Improved Stamps—Work done by them—Work done by American and Australian Stamps—Recently invented Stamps—Patterson's Elephant Ore Stamp—Sholl's Pneumatic Stamp—Husband's Stamp—Harris's Annular Stamp Head—Cox's Stamping Machine.

When brought out of the mine, metallic ores are usually more or less intermixed with each other, and with the various non-metallic substances in the midst of which they lay when in the lode or deposit. They have therefore to undergo various processes whereby they may become separated and concentrated to as good a marketable quality as possible.

I will now notice these processes in the order in which they occur, together with the principles on which they proceed. In doing this we will assume that we are following the processes employed in the preparation of lead ore, and we can turn aside, as may be required, to notice the variations of the processes as adapted for other metallic minerals.

Picking and sorting.—When lead ore is brought out of a mine, it is tipped over a strong grate, where a stream of water is generally caused to pass over it. The purest lumps of ore, which do not require further dressing, are here picked out, as are also stones known to be barren of ore. In the caverns and flats of the Carboniferous Limestone there are often great lumps of pure galena, which only require the clay chipped or washed off them before they are ready for sale.

Crushing.—All the lumps containing ore are placed on one side to be crushed, or otherwise broken into sizes suitable for the next operation.

The means formerly used for this purpose were very simple. The larger lumps were broken by heavy hammers, and still further reduced in size by spalling. This was an operation in which the lumps of ore were laid upon a flat bench of stone or iron, and struck with a large flat piece of iron fixed on the end of a handle of wood. In course of time a pair of rollers turned by the hand were also used in reducing the ore to its requisite fineness, otherwise it could by constant spalling be reduced to the same size. The process is still in use at mines where machinery has not been erected, and I saw it in operation in 1878 at a lead mine in Flintshire, which was returning 40 to 50 tons of ore per month.

More recently at extensive mines this first crushing and breaking of the ore has been better and more expeditiously performed by machines constructed for the purpose; the one known as Blake's Stonebreaking Machine, the invention of Mr. Blake, of New Haven, and manufactured in this country by Mr. Marsden, of Leeds, is the one in most general use. Latterly there have been modifications of this machine, which are known as the Alden, Archer's, Broadbent's, and Lester's. Blake's may be taken as the type of the group, and a representation of it is given in fig. 135, and the following description by the maker will enable the reader to understand its mechanism:

'The sectional elevation shows the position of the essential parts of the stone-breaker. A is the main framing, and B a soft cast iron plate interposed between the frame and the fixed jaws C^1 and C^2. In place of the tedious process of running white metal behind the jaws, they have now smooth soft metal strips, which form a perfect bearing; the same mode of securing a good bearing is also adopted for the movable jaws, C^3 C^4. The sectional jaws are obviously renewable one by one, and therefore derive the name "Reversible." When any jaw becomes worn, it only requires to be turned, and does not, as formerly,

necessitate an entirely new jaw; the upper sections which operate first on the stone "sledge" it, and the lower sections finally reduce it to the size desired. The connecting rod is double, and consists of two cast iron heads, G, with capbolts and wrought iron rods, H, keyed into the heads at the upper end, and looped round the steel pin I^2 at the lower end. The toggle plates K and J are solid, the pins I^1 and I^2 are likewise of steel, and their ends are secured by caps and bolts to the movable jaw stock D, and to the piece L respectively. From

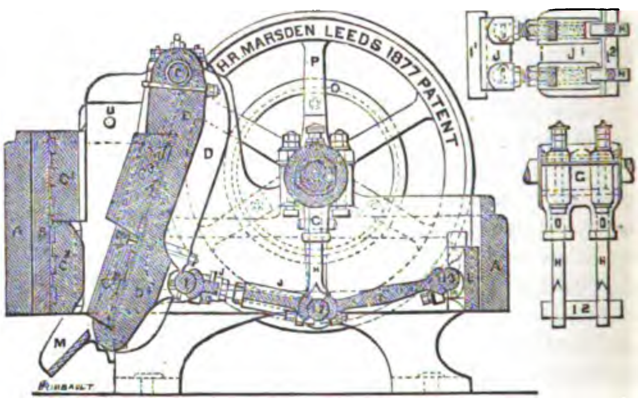


FIG. 135.—BLAKE'S STONE-BREAKING MACHINE.

the diagram it will be observed that the latest improvement consists in a modified arrangement of the toggles and connecting rod, with the object of diminishing friction; and from the results obtained in practice there can be no doubt that, in addition to a saving of power, a far larger quantity of material is treated. The machine has always been acknowledged to secure vast economy, and the long experience which Mr. Marsden has had in the manufacture of the machines, has naturally enabled him to remedy such trifling defects as required to be removed, in order to render the machine perfect.'

The work that can be accomplished by the different sized machines is thus given:

Size of machine mouth	Product per hour to road metal size		Maximum power required
Inches	Yards	Cwts.	N.H.P.
10 × 7	3⅓	83	4
12 × 7	4	108	5
15 × 7	5	125	6
15 × 9	6	150	8
20 × 9	8	200	10
24 × 12	12	300	12
24 × 16	13	325	14
24 × 18	14	350	16
30 × 12	14	350	16

It is found that when the ore is large it is convenient to use two machines, one for breaking the large and one for the smaller lumps. Practically, also, it has been found that a given quantity of ore, which has been broken by a machine, may be stamped, when this further operation is necessary, in seven-eighths of the time required for stamping ore broken by spalling, probably because it is fractured throughout.

Grinding.—The ore, after passing from the spaller, or from the stone-breaking machine, has to be still further reduced in size. I have said that this was formerly, and to some extent yet is, done by passing the ore through a pair of hand rolls. Ordinarily, now, these rolls are turned by water or steam. The ore is made to pass through them from the machine, and, when necessary, the process is repeated, the ore being brought up again by a wheel, on the inner side of which is a series of elevators, and the rollers being set closer and closer until the ore is of the requisite fineness.

This is the process mostly employed for lead, copper, and zinc ores, but for gold and tin a greater degree of fineness is required, which is attained by stamping.

Stamping and Stamps.—Stamps have been used in Cornwall from early times. These stamps, 280 years ago, were of a simple but effective kind. In general appearance they resembled the

kind shown in fig. 136, and the same description is still in use at some of the smaller mines in the country. They consisted of an upright beam of wood, A, shod with iron, and weighing about 150 lbs. This was raised by a wheel, B, on which there were cog-like projections, which when made larger were called cams. The beam was left to fall by its own weight. There were generally three or six of these worked together by a water wheel. The constant falling of the beams crushed the tin ore to powder, in which state it was at first carried away to be further treated. This was the dry method. Gradu-

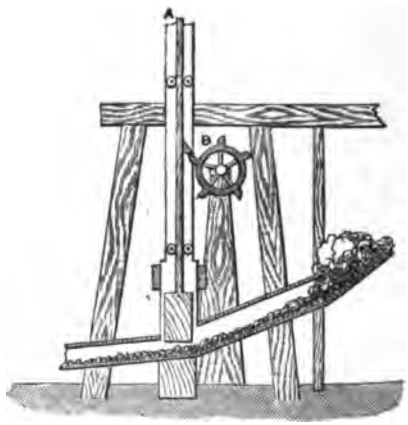


Fig. 136.—Old Cornish Stamp.

ally the practice grew of turning a stream of water upon the pulverised ore, which washes it through finely perforated iron plates into pits, where it is deposited according to its specific gravity. This is the wet method. In course of time, but not until recently, the wood beam was replaced by iron, and the weight increased. The bottom of the stamp was also made movable, so that it could be renewed. With these principal exceptions, this was the kind of stamp introduced into California and Australia, any modifications consisting chiefly in the machinery by which it was worked, and the addition of

the rotary process in which the stamp turns around as it strikes its blows. The first steam stamping mills in Cornwall are said to have been erected at Wheal Fanny in Camborne, and Wheal Vor, Breage.

For some time the utmost work done by these old stamps was the crushing of half a ton of ore per head in twelve hours. A modification of them erected at Wheal Basset Mine in Cornwall crushes 27½ cwt. per head in the same time. At St. Ives Consols Mine, a 26-inch cylinder engine worked 52 heads of stamps of 750 lbs. each, besides working a pulveriser, 20 round buddles, and 4 short pumps. The stamps crushed 1,000 tons of ore per month. Among the old stamps was a round one, of a weight of 900 lbs. and a movement of 80 blows a minute, with a drop of 9 inches at each stroke. The cost of pulverising tin ore by the ordinary Cornish stamps is estimated at 1*s.* 9*d.* per ton.

The following particulars[1] will illustrate the amount of work done by ordinary stamp mills in America at the present time:

Work recently performed by stamping machinery in America:

STANFORD MILL, AT WHITE PINE.

Silver Mill, Crushing Dry.

Number of mortars	6
Discharge of mortars	Double
Number of stamps to each mortar	5
Total number of stamps	30
Weight of a stamp in pounds	750
Height of drop in inches	8
Number of drops per minute	95
Screens made of brass wire	—
Trade number of the screens	50
Tons of rock crushed in 24 hours	52
Tons crushed per stamp per 24 hours	1·73
Quality of the rock	Hard
Formation	Limestone
Fineness of the bullion	998

[1] *Mining Journal*, July 28, 1877.

Meadow Valley Mill, at Pioche.

Silver Mill, Crushing Wet.

Number of mortars	6
Discharge of mortars	Double
Number of stamps to each mortar	5
Total number of stamps	30
Weight of a stamp in pounds	750
Height of drop in inches	9
Number of drops per minute	85
Screens made of Russia iron, punched	—
Trade number of screens	6
Tons of rock crushed in 24 hours	67
Tons crushed per stamp per 24 hours	2·07
Quality of the rock	Tough
Formation	Quartz
Fineness of the bullion	550

Raymond and Ely at Pioche

Silver Mill, Crushing Dry.

Number of mortars	6
Discharge of mortars	Double
Number of stamps to each mortar	5
Total number of stamps	30
Weight of stamps in pounds	750
Height of drop in inches	8
Number of drops per minute	95
Screens made of brass wire	—
Trade number of screens	50
Tons of rock crushed in 24 hours	48
Tons crushed per stamp per 24 hours	1·6
Quality of rock	Easy
Formation	Quartz
Fineness of bullion	775

St. Lawrence Mill, at Newcastle, Placer Co., Cal.

Gold Mill, Crushing Wet.

Number of mortars	1
Number of stamps to each mortar	6
Total number of stamps	6
Weight of a stamp in pounds	650
Height of a drop in inches	10

Number of drops per minute	90
Screens made of Russia iron, punched	—
Trade number of the screens	5
Tons of rock crushed in 24 hours	17
Tons crushed per stamp per 24 hours	2·85
Quality of the rock	Brittle
Formation	Quartz
Fineness of the bullion	—

EUREKA MILL, AT CARSON RIVER, NEAR VIRGINIA CITY.

Silver Mill, Crushing Wet.

Number of mortars	12
Number of stamps to each mortar	5
Total number of stamps	60
Weight of a stamp in pounds	950
Height of drop in inches	9
Number of drops per minute	90
Screens made of Russia iron, punched	—
Trade number of the screens	4
Tons of rock crushed in 24 hours	159
Tons of rock per stamp per 24 hours	2·65
Quality of the rock	Easy
Formation	Quartz
Fineness of the bullion	·980

WATER REQUIRED IN WORKING QUARTZ.

Each stamp uses 10 lbs. per minute. Each pan uses 16 lbs. per minute. Each settler uses 9 lbs. per minute. If the water is run from the mill into settling tanks it can be saved with a loss of 20 per cent. This will make the actual supply of water required in pounds per minute to be as follows: For one stamp, 2; one pan, 3·2; one settler, 1·8.

POWER REQUIRED FOR A 60-STAMP MILL.

60 stamps, at $1\frac{1}{8}$ horse-power	67·5 horse-power.
22 pans, at 4 horse-power	88·0 ,, ,,
11 settlers, at 3 horse-power	33·0 ,, ,,
3 concentrators, at 2 horse-power	6·0 ,, ,,
1 rock-breaker	5·5 ,, ,,
Friction	25·0 ,, ,,
Total power required	225·0 horse-power.

WATER REQUIRED FOR A 60-STAMP MILL.

225 horse-power	will require per minute	. .	169 lbs.
60 stamps	,, ,,	. .	600 lbs.
22 pans	,, ,,	. .	352 lbs.
11 settlers	,, ,,	. .	99 lbs.
	Total water required	. . .	1220 lbs.

Of which 1·051 lbs. used for stamps, pans, and settlers can be re-pumped to the tank at a loss of 20 per cent., and the 169 lbs. for the engine can be condensed at a loss of 50 per cent. This will leave the actual amount to be supplied as follows:

20 per cent. of 1·051 lbs.	210·2 lbs.
58 per cent. of 169 lbs.	84·5 lbs.
Total water per minute	294·7 lbs.

In No. 4 screens the holes are $\frac{1}{34}$th of an inch in diameter, and there are 144 holes to the square inch. In No. 6 screen the holes are $\frac{1}{40}$th of an inch in diameter, and there are 324 to the inch.

At Black Hill, on the River Yarra-Yarra, in Victoria, sixty stamps, weighing 700 lbs. each, crush 96 tons of clean hard quartz a day, or a little over 1½ tons each. The stamps make about 70 blows a minute and revolve. They are worked by a 100 horse-power double-cylinder engine, 18 inch, which, besides working the stamps, works two 13-inch plunger pumps, with other work besides. The cost of crushing the ore is 4*s.* per ton.

The work of an ordinary stamp may therefore be taken at a maximum of 1½ tons of ore crushed in twelve hours.

The attention of Cornish engineers has lately been directed to means whereby this result may be largely increased, by securing a greater number of blows of greater power per minute.

Among the inventions for this purpose are the stamps of Patterson, Sholl, and Husband. Patterson's Elephant Ore Stamp is provided with a spring, the action of which is to draw the stamp head back the moment the blow is struck, so that the rock is shattered into grains without being ground into powder. A machine with two heads is at work at Wheal Uny, Cornwall.

It is driven by an 8-inch cylinder engine, with 12-inch stroke and from 10 to 11 horse-power. Each head makes nearly

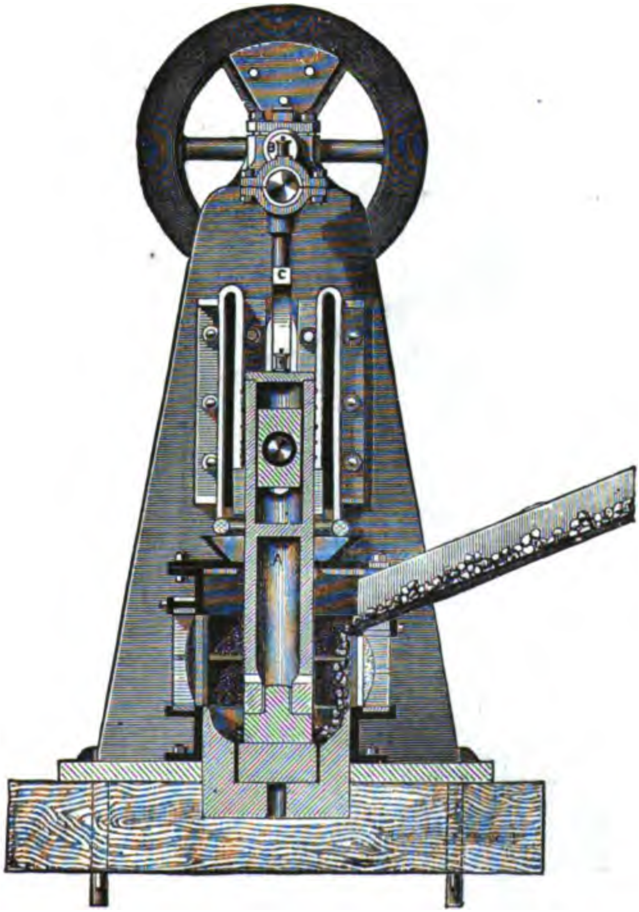


FIG. 137.—SECTIONAL VIEW OF SHOLL'S PNEUMATIC STAMP.

130 strokes a minute, and the ore is passed through a very fine grating at the rate of 1 ton every 75 minutes, or about 9 tons

in 12 hours. The cost on ore to the extent of 1,800 tons a month is estimated at 9*s*. per ton.

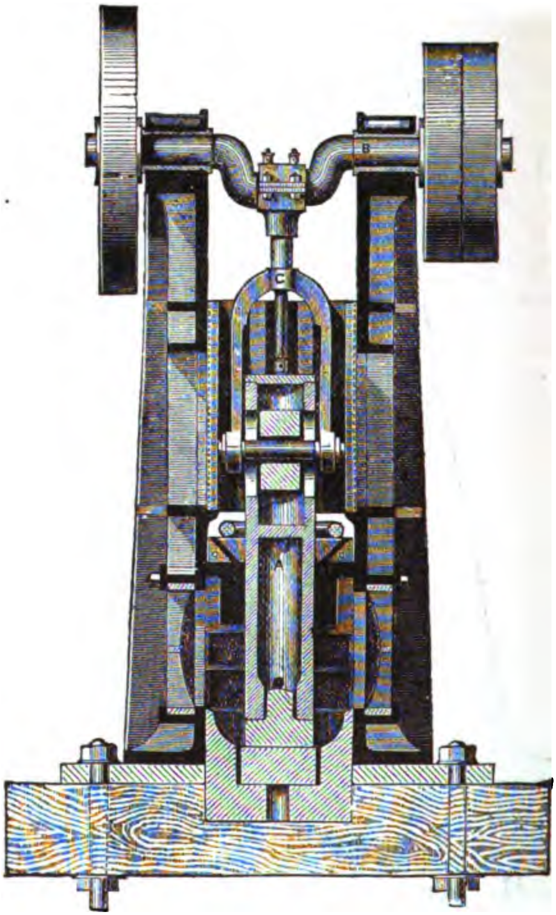


FIG. 138.—FRONT VIEW OF SHOLL'S PNEUMATIC STAMP.

Illustrations of Sholl's Pneumatic Stamp are given in figs. 137 and 138, and may be thus described:

The stamps are either fixed on a suitable foundation, or are self-contained. The direct-acting stamps are driven by steam direct, and compress the air on two sides of a piston in the pneumatic cylinder and stamping stem. It is from this arrangement the cushioning principle is obtained to counteract the violence of the descending blow of the hammers or stampers.

As the piston descends into the air cylinder it compresses the air, and thus provides an elastic agency competent to regulate the blow of the hammer to the required stroke, and thus in effect converting it into a self-regulating action capable of overcoming any danger which may arise from a negligent supply to the hopper. The maximum number of blows per minute are 150, and it is claimed for this stamp that, owing to the peculiar character of its principle, much smaller stamps can be used either for prospecting purposes, or where portability becomes a necessity through bad roads, &c.

One of these stamps is in use at the Botallack Mine, Cornwall, where the tin ore has to be powdered very fine. It passes one ton per hour through No. 36 wire gauge grates, making 145 to 150 blows a minute.

Husband's stamps are somewhat similar, employing an air cushion or break in the same way. One in use at Smeddle's gold mine, in Nicaragua, has a head weighing, with everything attached, 830 lbs. It reduces 12 tons of quartz ore so that it will pass through fine gratings every 10 hours.

In stamps having a head with a large surface there is a difficulty in getting the powdered ore away from the centre. To obviate this difficulty Messrs. Harris & Rounsivello have contrived a large head, with a round hole through the middle of it, down which the water and ore are supplied; and Mr. S. H. F. Cox has invented a machine to use this head which weighs one ton, and by the aid of two large cams, worked by steam, he proposes that it shall give 200 blows a minute. As far as experience goes, however, a head of moderate weight working quickly is better than a very heavy head which reduces the tin ore to slime, and which in the case of

gold would make the particles so small that they would flow off in the waste water. On the other hand if gold quartz ore is not crushed fine enough the grains of gold are lost, embedded in the waste quartz. Each mine, almost, requires its own adaptation of stamping power and machinery.

CHAPTER XXXVIII.

ON THE DRESSING OF METALLIC ORES—Continued.

Jigging—The Different Specific Gravity of Different Mineral Substances, a reason why they can be mechanically separated—Table of Rates at which various substances fall through Water—Introduction of Hand Jigging—Mechanical Jigging—Principle of Jigging—Jigs with Movable Sieves—Jigs with Fixed Sieves—Self-acting Continuous Ore Dressing Machinery—Green's—Rotating Jig or Buddle—Buddles—Ordinary Round Buddles—Slime Pits—Tozing—Machinery for Retreatment of Ores—Dressing Tin, Copper, Silver, Gold—Methods pursued in Brazil and in Victoria.

JIGGING.—It will have been observed that the various metallic and non-metallic substances noticed in these pages are of different specific gravities; and it is this fact which is taken advantage of and utilised in cleansing and separating the metallic ores after they leave the stamps or grinding pans and mills.

Being of different weights compared with an equal bulk of water each metallic ore takes a different portion of time in falling through a given space of water. The following German table of these velocities, given by Dr. Raymond,[1] will illustrate this difference:

TABLE SHOWING THE DISTANCE IN PRUSSIAN INCHES THAT SPHERES OF VARIOUS SIZES OF DIFFERENT SUBSTANCES WILL FALL THROUGH WATER IN ONE SECOND OF TIME:

Diameter in lines	Gold spec. grav. 19·2	Galena spec. grav. 7·5	Blende spec. grav. 4	Quartz spec. grav. 2·6
8	100	60·093	40·825	29·814
5·657	84·090	50·532	34·329	25·071
4	70·711	42·492	28·868	21·082
2·828	59·460	35·731	24·275	17·728
2	50	30·046	20·412	14·907
1·414	42·045	25·266	17·165	12·535
1	35·335	21·246	14·434	10·541

[1] *Mining Statistics of the West.*

Now, taking galena, as in the last chapter, to start with, we see that it is half as heavy again as blende, and as heavy again as quartz, its two chief associates. The earliest attempts to utilise this difference in weight was by hand jigging, which, by means of a sieve in which the combined ores were shaken up and down in water until the lead took the lowest, the blende the middle, and the sand and clay the uppermost place, seems to have been first practised in Bohemia in 1519. After this the sieve was attached to a frame, and the shaking done by boys or girls by means of a lever handle, both plans being still in operation. Between 1840 and 1850 the plan was adopted of attaching four or five of the movable sieves to a shaft

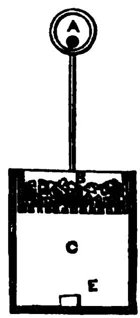


FIG. 139.—JIGGER, WITH ORE IN PLUNGER.

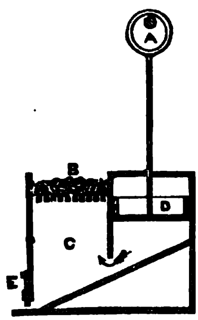


FIG. 140.—JIGGER, WITH ORE IN FIXED TROUGH.

turned by a water wheel, in the manner shown in fig. 139, A being an eccentric turning on a shaft, B the sieve containing the ore, C a box or hutch containing water. At every revolution of the shaft, therefore, the sieve B would be shaken up and down in the water, which, passing through the sieve, would gradually sort the materials, the lead occupying the lowest place as before described.

More recently the fixed or stationary sieve, as shown in fig. 140, was adopted. A, the eccentric on shaft, B the sieve containing ore in box or hutch C, and D, the plunger, which is worked up and down at every turn of the shaft, and in so doing forces the water in the box C up through the ore, by which

means the ore is washed and arranged in the manner already described. This fixed sieve seems to have been first introduced into Hungary in the year 1828, and into Cornwall by Captain Petherwick in 1832. These two processes form the base or principle on which all subsequent elaborate jigging machines and processes are founded.

It should be explained that a layer of clean ore of a larger size than the mesh of the sieve is placed at the bottom of the sieve, and through this, in the process of jigging, all the ore of a smaller size than the mesh of the sieve finds its way into the hutch below, from whence it is taken at the doors or valves E E. When the sieves and hutches are placed in a row, each one is finer than the last, until at last only very fine tailings or wash flows off to the next process.

The next step in advance was to make all the operations from the crusher or stamps self-acting, so as to save time and cost of labour. A process by which this might be accomplished seems to have been invented simultaneously by two Germans, Vögel of Joachimsthal, and Wimmes of Clausthal, in the year 1850. This object has now been accomplished to great perfection. A variety of very ingenious and complicated processes are adopted at the mines of the Hartz [1] and Erzgebirge, and perhaps one of the best examples of this continuous process may be seen at the Van Mines in Montgomeryshire.

In this country Mr. George Green, of Aberystwith, has paid great attention to the whole question of the dressing of ores, and figs. 141, 142, and 143 represent his patent Self-Acting Dressing Machinery, and they will serve as an illustrative example of this class of ore-dressing machinery.

In fig. 141, A is the crushing mill, with rollers 26 inches in diameter, into which the ore stuff to be treated is put. When these rollers are started, the whole of the machinery is set in motion, and the work goes on regularly without hand-dressing. B is a revolving classifier which receives the crushed stuff from the rollers. The perforations in this classifier have their size

[1] For elaborate descriptions and illustrations see *Mining and Engineering Journal of New York*, 1878.

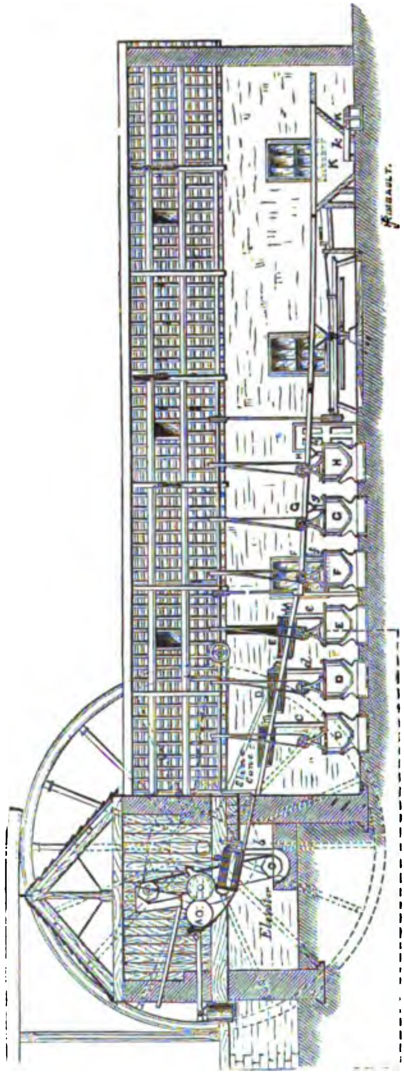


FIG. 141.—CONTINUOUS ORE-DRESSING MACHINERY-ELEVATION.

adapted to the kind of ore to be treated—the richer it is in mineral, the larger the holes, and the poorer it is in mineral the smaller the holes. Lumps not sufficiently broken are carried back to the crusher by the elevators A, while all that passes through the holes is delivered into an iron trough B, which conveys it on to the next operation, which is performed by C, D, E,—which are three of Green's Patent Automatic Classifiers and Feeders. Each of these classifiers is covered with perforated iron plate of a suitably-sized perforation to suit the first classifier, B, each descending one being finer than the one above, so that B, the first, is the coarsest, and E, the fourth, is the finest. Perforated pipes are placed inside each classifying trommel, from which a sufficient quantity of water plays on the ore stuff to wash through the

perforated plates all the slimes and particles which are finer than the holes—thus all that passes through the perforated plate of one classifying trommel is discharged into the next in succession, whilst a sized product is discharged at the end of each into iron troughs or shoots, *c*, *d*, *e*, which convey it into a jigging machine to suit. In succession, then, each classifying trommel discharges a sized product entirely free from slime, and out of the trough (*e*) surrounding the last, all the slime and finer particles are discharged into a *launder*, which carries them to be treated

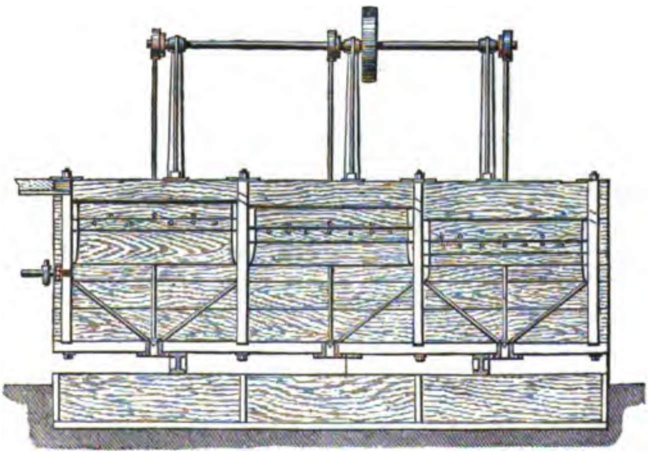


FIG. 142.—ELEVATION OF JIGGERS.

apart from the rougher ores in F, G, H, I, K, which are five patent saddle-back classifiers and feeder, and which are made with inclined sides meeting in an inverted pyramidal point at the bottom. A current of water with the slimes, &c., delivered by the last riddle in suspension, flows into a classifier at one end, deposits some of its suspended matter, and flows off at the other end into a second classifier, and then onwards to the others. These classifiers are of graduated sizes, the first in order being the smallest, and the current flows through them at different velocities—so that in the first and smallest, the current being the

strongest, the largest particles are deposited, and smaller ones in the next, and so on. The smaller classifiers are provided with water pipes attached at the bottom to deliver a spray of clean water at a head of 15 or 20 feet pressure, and sufficient in volume to carry forward the dead slimes to the last and largest classifier, where the current is very slow and weak, and which has no pipes connected for clean water—the current being almost stagnant in this; all ore worth saving is sure to deposit itself. The classified stuff from F, G, H, is delivered by the troughs *f*, *g*, *h*, into the jiggers F, G, H, and the stuff from I and K through troughs *i*, *k*, into either buddles or trunks.

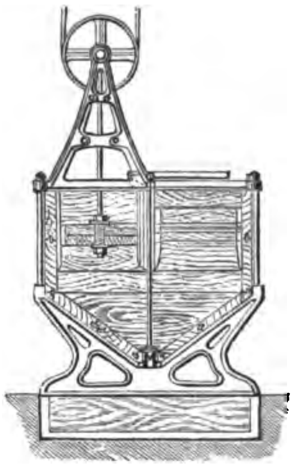


FIG. 143.—ELEVATION OF JIGGER'S ENDS.

C, D, E, G, H, are six of Davies's Patent Three Compartment Jiggers, which receive the classified stuff delivered by the classifiers as explained above. The jigger comprises a horizontal hutch, constructed of wood or iron, which is divided into two, three, four, or more compartments, by transverse ends and partitions. A vertical partition extends along the upper part of the compartments; and on one side thereof there are a set of plunges or pistons to produce the jigging motion of the water, whilst a series of sieves are placed on the other side. On the top of the partitions there are fixed a number of standards to carry a longitudinal shaft on which the eccentrics are fixed, and which being connected by rods to the plungers put the water in motion. The separation is effected by the jigging action of the water with which the hutch is filled, and which is made to work up and down through the sieves by the plungers. A layer of ore is put on the sieves, which has the effect of allowing particles of the same specific gravity as itself

to pass through, whilst it keeps back any particles of less specific gravity, which last are gradually washed over the end from each compartment to the next lower one—the light waste from the last compartment finally passing away. A suitable appliance for regulating the stroke of each plunger is attached.

Buddles, or other efficient slime machines, are attached to the larger classifiers, and the stuff flowing in a perfectly even current from the bottom of such classifiers on to each separate buddle, makes them quite self-acting, and of course more effective. All the labour required is to raise the deposited ore out of the jigger receiving box, and off the beds or buddles, to make room for other deposits. The finest or dead slimes are worked by an ordinary paddle trunk. The whole is complete and continuous, and worked without labour from the roughest prills to the finest slimes—each distinct size having a machine suited in speed and action for its treatment. A good many of these machines are now working successfully in this and foreign countries. At some mines, in addition to the jiggers, a rotating buddle or jigger, of which a section is given in fig. 144, is used for separating the larger ore. The ore is supplied with a plentiful stream of water at A; it tries to fall down the concave slope B, but is thrown back repeatedly by plates placed diagonally on a revolving light framework cylinder C. The light earthy matter escapes into the trough D, and is taken away for further treatment. The larger ore, cleaned as it travels, is carried along the buddle for about 8 or 10 feet, and is thrown out in a clean state at the other end.

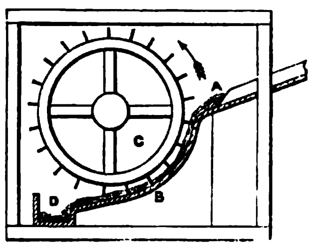


FIG. 144.—ROTATING BUDDLE OR JIGGER.

Buddles and buddling.—The slime that flows away from the processes just described has to be further treated by buddling. An ordinary buddle is a circular hole or framework let in the ground, as shown in fig. 145.

A A represents the slime and water flowing from the jiggers.

This flows over the central boss B, and runs down the sloping floor C C. In doing this the particles of lead being heaviest are deposited first, about 1 1. The blende is next deposited, about 2 2, and the earthy matter lowest, about 3 3. D is a piece of cloth attached to a frame E, which turns around the central pipe or stem, and smooths the surface and helps to distribute the materials over the whole floor.

There are long buddles with gently sloping floors, and many adaptations of the principle here illustrated. Usually the waste flows from the buddles to the slime pits, where any particles of lead there may remain sink lowest, and are ultimately recovered; and, passing through a number of such pits, all the mineral matter in the water settles down at last, and the

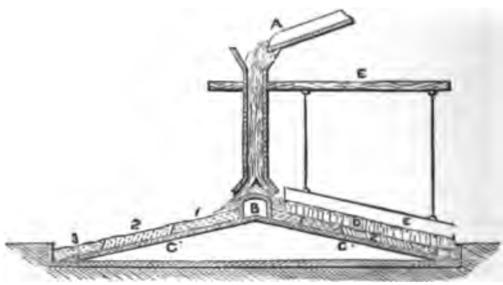
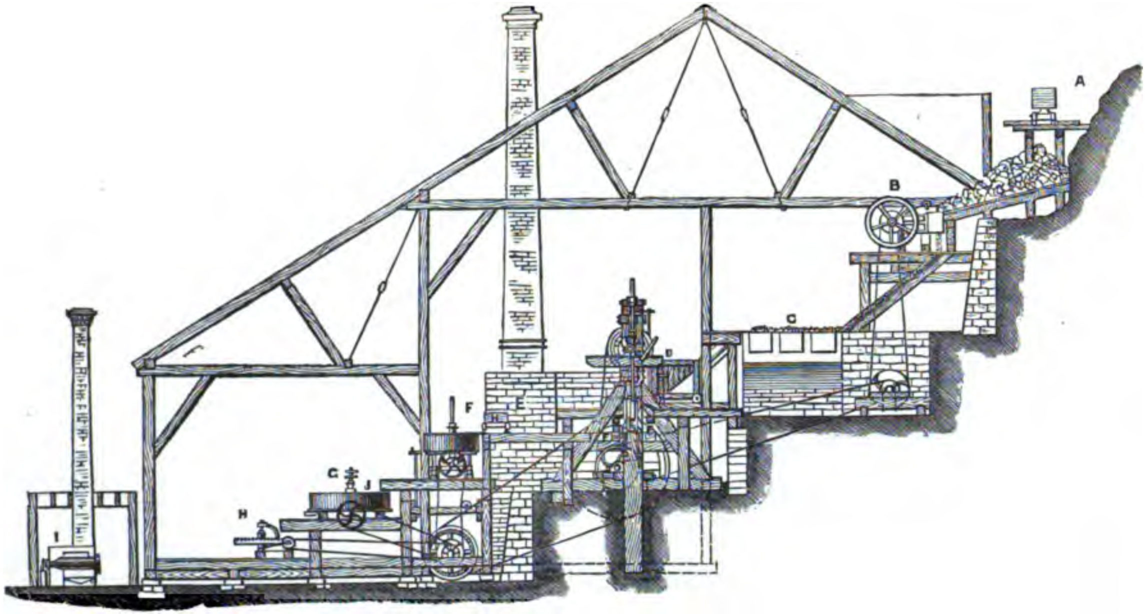


FIG. 145.—ORDINARY CIRCULAR BUDDLE.

water, but for the colouring matter it has received, flows off comparatively pure.

Latterly, contrivances similar to those just described, but more delicate in their operation, have been adopted for the further treatment of the slime and waste. A series of these has lately been erected at the Van Mines, at a cost of about 6,000*l.*, and a profit of some 6,000*l.* to 7,000*l.* a year is made by treating over again the waste heaps at the mines. At some mines the fine slime flows into tubs, which when full are beaten with blows all around, like the 'tozing' of tin, which process helps the fine particles of lead to sink to the bottom, whence they

Fig. 146 — Arrangement of Silver Mill.



A, Tram bringing ore from mine. B, Blake's ore crusher. C, Kilns for drying ore. D, Stamps for powdering the ore. E, Roasting furnace. F, Pan for working the ore in batches, so as to wash off earthy matter. G, Pan in which the ore settles. H, Hendy's concentrator, in which the ore is further purified and concentrated. I, Retort for separating the amalgam.

are recovered. Lead ore is usually dressed to a quality of 75 to 76 of metallic lead.

For most copper ores the process of treatment is similar to that described, but the average final proportion of metallic copper in the ores of this country is, as we have seen, from 6 to 7 per cent.

The process of jigging is dispensed with for the most part in the treatment of tin ore, for, being powdered very fine, it flows at once to conical buddles like those just described. It is further treated sometimes in a concave buddle, known as Borlases, where the heavy tin ore accumulates in the centre. It is also treated in sloping pits and in tubs by tozing, as already described, frequently by roasting in addition, to drive off sulphur, until, as black tin, it is fit for the smelter. In 1877, 14,142 tons of dressed ore produced 9,500 tons of metallic tin, and a similar proportion has prevailed since the year 1872, so that we may regard 100 lbs. of tin ore as equivalent to 70 lbs. of block tin.

Silver is, for the most part, as we have seen, a chemically-associated metal, and it is not often that the whole proportion of silver in its ores can be extracted without passing them through the smelting house. Fig. 146, adapted from Dr. Raymond's book, is the representation of an ordinary silver-dressing mill in Western North America.

The last reference shows that mercury is used to some extent to separate the silver.

Gold.—As finely-pulverised ore containing gold flows through the fine gratings from the stamps, many processes are used in order to intercept the precious metal, the principle of which may be summarised in the order followed, thus:—1. Gently sloping troughs, across which are nailed thin boards or riffles, which intercept the heavier particles of gold. 2. Hides with the rough hair upwards, which still further arrest the grains of gold, as the grass formerly did before mining began. 3. Rough blankets, spun on purpose, of a hairy kind, which intercept the finest grains. The natives of Aruba Island, one of the Leeward Islands in the Caribbean Sea, pour the water con-

taining the gold upon the woolly head of one or more of their number, which is a very effectual means of arresting the gold. The two last of the foregoing processes are assisted by the use of mercury, between which and gold there is a great affinity. This is spread on the hides and blankets, or upon copper plates laid in the troughs, or poured in with water flowing from the stamps, when the grains and particles of gold and it coalesce and form an amalgam, from which the mercury is afterwards separated, to be used over again. The details of the ordinary process followed at St. John del Rey Mines in Brazil may be briefly stated thus. The pulverised ore and water running from the grates near the stamps is further diluted with clean water, and is conducted over slightly inclined tables or 'strakes,' which are from 27 to 35 feet long and an average of 1 foot 6 inches wide, with a fall of one inch in a foot. Bullocks' hides, tanned with the hair on, are spread over the first sixteen feet of the strakes, and baize cloths are placed below, followed below by another series of overlapping skins. These skins and lengths of baize are washed at regular intervals in separate tanks, and the product amounts to 0·42 of a cubic foot per ton. This sand goes to the amalgamating house. The sand from the middle strakes contains some 6 ounces of gold per ton, and is further enriched by being washed over another system of strakes. The products of the lowest skins are called 'tail sand,' and they are treated over again.

At Mount Egerton, in Victoria, the powdered ore is washed into lockers, where it is received on trays placed one over the other, and which have perforated sides, and contain quicksilver in the bottom. The loose gold is quickly acted upon by the mercury, and an amalgam is formed; the water carrying away the sand which flows over inclined planes or 'strakes' covered with blankets containing quicksilver. On these part of the remaining gold is caught. But out of the tailings the Chinese, by repeated washings, contrive to earn wages reaching often as high as 10*l.* a week. At St. John del Rey, too, a good proportion of gold is lost, and the same is true at most gold mines.

Still, if the Chinese, by painstaking, make money out of the tailings, the white men ought to do so also.

The details of the processes employed vary in different parts of the world, but the principles on which they proceed are the same everywhere. We shall have to refer again to them in the next chapter, which treats of hydraulic gold mining.

CHAPTER XXXIX.

HYDRAULIC GOLD MINING.

The Pan—Cradle—Long Tom—Broad Tom—Artificial Sluice—Natural Sluice—Top unproductive Drift—Mining—Hydraulic Excavation—Runs—Cleaning up, &c.

THIS is the name now given to the various processes by which gold is sought for in the superficial alluvial drifts.

The Pan.—The earliest adventurers used simple pans or shallow dishes, in which the auriferous drift was washed by hand. Pans are still used by adventurers and prospectors in new gold fields. They are nicely turned wood bowls, or pans of copper or brass, about 16 inches diameter and nearly 2 inches deep in the middle. By careful manipulation the grains of gold collect in the deepest part of the pan, where they are of course secured.

The Cradle.—Following the pan came the 'cradle,' which was a wooden box, about 3 feet 6 inches long and 1 foot 6 inches wide. It was placed in a sloping position, and fixed upon rockers. It had also a movable hopper and slides. The gravel was well shaken and washed in this, the contained gold being secured in the lower part of the cradle.

The Tom.—Following the 'cradle' came the 'tom,' which soon became divided into 'long toms' and 'broad toms.' The 'long tom' was a wooden trough or box, from 12 to 14 feet long and 18 inches wide. It had a grating in the bottom, at the lowest end, when the tom was placed in a gently sloping position for use. Underneath this grating was placed another wooden trough, across the bottom of which were fixed thin pieces of wood or riffles. The whole apparatus was fixed in a

gently sloping position, near the face of the excavation, over the top of which a stream of water was conveyed to the upper end of the tom. Into the upper trough, with the stream of water running through it, the auriferous earth was shovelled, and if at all stiff it was stirred and worked by a man. The grate at the bottom intercepted the larger stones, which were removed. The smaller stuff containing the gold fell into the lower box, along which the lighter earth was carried off by the water, the gold, from its greater gravity, being intercepted by and resting against the cross bars or riffles.

The 'broad tom,' or 'Victoria Jenny Lind,' was the same in principle, but was made only about half the length of the 'long tom.' It was also made only 12 inches wide at the upper end, but it opened out to a width of 3 feet at the lower end.

The Sluice.—Gradually, and almost universally, the 'tom' was superseded by the sluice, which is of two kinds, the natural and the artificial. The natural sluice is a long channel cut in the floor of the excavation, having a slope or inclination wherever possible, of only one in forty or fifty. The bottom of this channel, even if it be on the bed rock of the country, is not of itself hard enough to stand the abrasion of the water and of the drifted matter running over it. It is therefore covered with boards or rough planks, or it is paved with hard stones with the grain placed vertically. These are not less than 20 lbs. weight, but they are often swept away by the force of the water. Where the wash-earth is soft and loose either of the two first basements will do; but where it is tough and hard the pavement of stone has to be adopted.

The *Artificial Sluice* consists of a series of troughs about 12 feet long, like the upper trough of the 'long tom.' These are made of rough boards, the lower end being made smaller to fit into the end of the next trough, and at the lower end of each trough a bar or grating is usually placed to intercept the coarser stones which are thrown out. The troughs are also often provided with a loose bottom, perforated with holes, through which the gold and small dust sink into the bottom of the trough.

These troughs are fixed on trestles at a slope of one in forty or fifty, the slope depending upon the quantity of water avail able. If this is small the slope must be greater, but if the supply of water is plentiful the sluice is placed as slightly sloping as possible.

In sluices of both kinds the auriferous dirt is placed at the upper end of the sluice, and the particles of gold sink in the interstices of the pavement or other bottom of the natural sluice, and on the lower bottom, or against cross riffles in the artificial sluice. The gold is most effectually saved where the sluice is long and the inclination very gentle. The ground sluice requires six times more water than the artificial sluice, but it wants less manual labour. The adoption of either plan at a mine depends, therefore, upon the relative cost of water and men in the particular district.

In the case of the 'long tom' and the artificial sluice the 'wash-dirt' has to be lifted into the upper end by manual effort; but where ground sluices are available the aid of water is employed in the process.

The auriferous drift is, as we have seen, covered with a greater or less depth of other unproductive drift, which has to be got rid of. In Australia, when this covering is only 10 feet thick and under, it is removed, and thrown on one side. If it is between 10 and 30 feet in thickness, and it is of a hard and compact nature, the underlying auriferous drift is mined, and the top left standing. When the top drift is over 30 feet thick, whatever its nature the underlying gold drift is generally mined.

Supposing the gold drift to be worked in an open excavation it is worked much the same as a railway cutting is carried forward. Then if a good supply of water is available, a stream is turned on to the earth thus obtained, which is thus washed into the ground sluices prepared for it. If the process of extraction be mining, the earth is similarly placed under the influence of a stream of water; and this remark will apply to those older and deeper auriferous drifts which, as we have seen, figs, 30, 31, and 32, lie under tertiary basaltic deposits.

In both cases the rougher stones are thrown out along the course of the sluice.

In Australia, where the bed rock under the auriferous drift is granite, tin ore is often found in its disintegrated upper portion, and hence sometimes alluvial tin mining becomes the

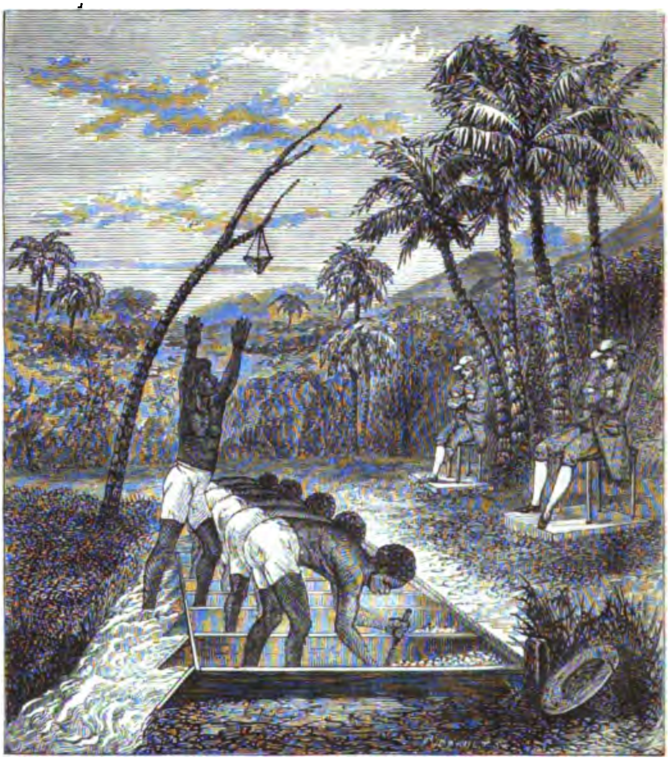


FIG. 147.—PRIMITIVE MINING—NEGROES WASHING FOR DIAMONDS, GOLD, &c.

most profitable of the two. The forms of the grains of gold are found to differ according to the nature of the underlying rock. If it is slate the grains are cubical, if granite they are flat plates and scales.

Hydraulic Excavation.—More recently, and especially in California, water has been employed, instead of men with picks and spades, to tear down the face of the excavation before it is used to convey the drift along the sluices. We thus reach the opposite of the early condition of alluvial mining. At

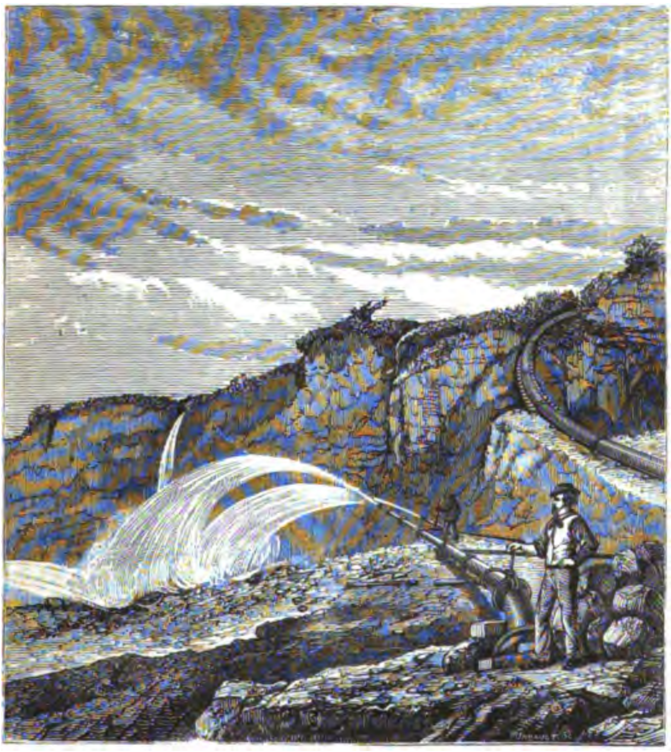


FIG. 148.--MODERN HYDRAULIC GOLD MINING.

first the drift was carried in small quantities to the water, now the water is brought in large quantities to the drift.

Figs. 147 and 148 illustrate these two opposite conditions. Fig. 147 is an adaptation from the old work of Maw, on his

'Travels in Brazil,' showing the primitive way of washing for gold and diamonds by the slaves, and one certainly cannot envy the position of the overseers. Fig. 148 illustrates the ordinary method of modern hydraulic gold mining. In the latter case the water is often brought from a great distance, and at a considerable expense, in pipes or 'flumes,' as seen in the right hand corner of the figure. It is thrown against the face of the excavation from a nozzle, which is of various kinds, and which is attached to the flume by a flexible hose. The force of the water is very great, and the gravel, sand, or mud bank is by this means easily undermined and washed away.

This method of mining is most advantageous where the face of the drift is from 30 to 60 feet in depth. It is safe also for the men, who are in no danger, as in the work of ordinary excavating, of being buried under the falling *débris*.

In this case the overlying unproductive drift is not first removed, nor has mining to be resorted to, but the whole of the drift is brought down and passed through the sluice.

Hydraulic mining of this kind is not so applicable to Australia, because of the usual flatness of the ground, and the consequent difficulty of finding fall for the water. Australian gold, too, is more flaky and light than Californian, so that greater care and skill are required in intercepting it, lest it should float off with the water.

The wooden sluice in California is made of half-inch boards rough from the saw. It is 16 or 18 inches wide, and it never exceeds 5 feet. Its fall or 'grade' is from 8 to 18 inches in 12 feet. The stream of water is usually about 2 inches deep over the bottom. There is also a false bottom, as in the 'long tom,' which is perforated with holes, and under this is the true bottom, on which are wedged riffles, which are placed sometimes longitudinally, with the pieces across, so that the bottom is divided into panels or compartments, and sometimes diagonally across the trough. An average number of twelve men are employed to throw the wash dirt into the sluice, and each man will throw in from 2 to 5 cubic yards a day.

Run.—The riffle bars soon wear out, and the time they last

often determines the length of the 'run,' or period during which the gold is allowed to accumulate in the sluice, otherwise the 'run' generally lasts from six to ten days.

Cleaning up.—At the end of these periods comes the cleaning up. At these times, which last from half a day to a day, the men cease throwing wash-dirt into the sluice. They take up the riffle bars for a length of about 30 feet. The water flows on and washes the gold to the top of the remaining riffle bars, where, any dirt remaining having been washed lower down, the gold is scooped up with a spoon into a pan, where it is finally washed and separated. Another length of riffles is then taken up, and the process is repeated until the whole sluice is cleared.

The extraction of the gold from ground sluices that are paved with stone is a more difficult process, and the gold dirt collected in it has afterwards to be treated in a broad sluice or 'tom.'

The extraction of the finer particles of gold is assisted by the use of mercury. This metal is allowed to drop into the uppermost end of the sluice, and it usually amalgamates with the gold before these two metals have gone far down the sluice, both of them stopping at the first resting-place.

Sluice troughs are sometimes made double, so that there need be no stoppage while the process of clearing up is going on. The arrangement also permits two companies, when they can agree to do so, working side by side.

Tail sluices.—There are also tail sluices, which are often placed in the bed of a stream, where the 'tailings' from the first sluice are treated over again. Occasionally the water flowing along the floor of a tunnel in a mine is used for the purposes of a sluice. Some comparisons of the costs and results of the various methods of extracting driftal gold just described are given in the next chapter.

CHAPTER XL.

SUNDRY PARTICULARS OF WORK AND COSTS.

GOLD—Quartz Mining—Alluvial and Hydraulic Mining—Tables of Particulars.—SILVER—Altai Mountains—Dry Ore Concentration—Mode of Treatment in Mexico—Copper Cape Mines—Algerian Mines—Parys Mountain Mines—Lake Superior Copper Mines.—TIN—Costs of Work in Cornwall—Percentage of Black Tin to Ore; of Black to Metallic Tin—Cost of Dressing—Cost of Prepared Ore per Ton—Banca, Australia, Red River, Cornwall, Stream Tin Workings.—LEAD—Various Costs—Zinc—Various Costs.—IRON—Various Costs—Deepest Mine Shafts in the World.

THE following particulars of work and costs derived from various sources will, I hope, be permanently useful for reference, and they will be of interest as showing prices paid and work done up to the present time.

GOLD.—*Quartz mining.*—In Victoria recently seven mines produced a total of 25,783 tons of quartz, which was obtained from depths of between 400 and 500 feet. This quantity gave an average of 6 dwts. 7 grains of gold per ton, or of the value of about 1*l.* 5*s.* per ton of quartz. The lowest amount was 4 dwts., and the highest 12 dwts. 6 grains.

29,324 tons of quartz taken from five mines, at depths of from 500 to 600 feet, gave an average of 8 dwts., or one-third of an ounce per ton.

17,377 tons of quartz raised from three mines, at depths of from 600 to 700 feet, gave 11 dwts. 6 grains per ton, or of the value of about 2*l.* 2*s.* to the ton of quartz.

The foregoing figures do not favour the theory that quartz lodes become less productive of gold in depth, as indeed, if they continue in the same strata, they should not.

There are also rich discoveries at great depths; thus at Mariner's Reef, 83 tons of quartz gave 5 oz. 3 dwts. of gold per ton.

Again, 32 mines in Victoria, with depths ranging from 180 to 650 feet, yielded on an average 11 dwts. 4 grains of gold per ton, the lowest being 1 dwt. 18 grains, and the highest 4 oz. It is considered that a yield of from 2 to 3 dwts. of gold per ton of quartz will pay for crushing.

The lodes or dykes in the above cases varied in width from 4 inches to 120 feet, the mean width being about 8 feet, each lode varying in width in its course downwards and horizontally. The cost of pumping averages 3*l.* a day. The cost of raising 1 ton of quartz from a depth of 550 feet was 9*s.* per ton. The cost of sinking shafts was 10*l.* per foot.

At Black Hill, on the River Yarra-Yarra, the cost of getting quartz per ton is, in an open quarry 4*s.* 2*d.*, in underground mining 9*s.* The cost of crushing was 4*s.* per ton. The average yearly earnings of gold miners have increased from 93*l.* 16*s.* 2*d.* in 1873, to 110*l.* in 1876. At the Little Annie Mine in Colorado, which is interesting as being one of the two highest mines in the world, 382 tons of rock were crushed in the close of the year 1877, at the rate of 8½ tons every 24 hours. The value of the gold obtained was $4,580, and the cost of mining and crushing $1,945, the yield of gold per ton being $1,199. In the beginning of 1875, 1,024½ tons were crushed, which gave $10,507; the cost was $8,763. 18c., or a net profit of about 7*s.* per ton of ore. The Americans can, generally speaking, quite equal the Australians in making a small proportion of gold pay a profit.

Alluvial and hydraulic mining.—In Australia four men filling a long tom, or raised sluice, will remove and wash 24 cubic yards of ground per day—6 cubic yards per man. In ground sluicing with a sufficiency of water the results will be more, varying with the skill of the men, the inclination of the sluice, and the density of the ground. A favourable instance is given of operations in the hill overlooking Allan's Flat, Yackandanah. The ground sluiced was a quartzosed gravel

3 feet deep, the quantity of water used was about 500 gallons a minute, the number of men 3, and the ground removed 150 cubic yards a day = 50 yards a man.

In *hydraulic* or *jet mining* the results vary according to the quantity of water employed and the height of its source, or its immediate fall above the point of operation, together with the compactness or looseness of the ground. The quantity of earth removed varies from 50 to 200 cubic yards a man. The costs of working a face of drift per day are thus estimated :

	£	s.	d.
Three men, at 8*s*. each	1	4	0
360,000 gallons of water, at 0·33*d*. . .		10	0
Repairs and renewals		6	0
	2	0	0

In average claims $\frac{4}{5}$ of a grain of gold per cubic yard will cover costs. In favourable hydraulic mining the costs have been defrayed by a less proportion per cubic yard. The two following tables, given by Mr. A. J. Bowie,[1] will afford very full particulars of work, costs, and results at two of the claims of the La Grange Hydraulic Mining Co. in California.

SILVER.—In the Altai Mountains, in the south-east of Siberia, the silver ore is quarried in open excavations, as well as in underground chambers, and after being picked and sorted the silver is obtained by smelting.

The following account by Herr Richter[2] of the processes employed in the reduction of silver in Mexico gives many details of work, and it will supplement the brief reference to the dressing of silver ores given in chapter xxxviii.

The ores raised at the Tajo Mine at Rosario, near Mazatlan, are essentially mixtures of quartz with argentic sulphides, and probably some silver and gold, together with some galena, brown blende, and pyritic minerals ; the average contents of silver being 40 ounces and of gold $2\frac{3}{4}$ ounces per ton, with from 6 to 8 per cent of lead and zinc. The reduction is effected by

[1] *Engineering and Mining Journal*, December 15, 1877.

[2] *Zeitschrift für Berg-, Hütten- und Salinenwesen*, vol. xxiv. p. 264, as translated in the *Proceedings of the Institution of Civil Engineers*.

From June 1, 1874, to October 3, 1876,	From February 12, 1875, to September 26,
15. 1, 2, 1, 1 2 1 1 1 1	2.

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the American method of pan amalgamation without previous roasting. The ore is partially divided, by hand-picking, into rich and poor classes, without, however, attempting to remove any of the lead or zinc minerals, which are passed by a mill of twenty stamper-heads, with rotating lifters weighing 7 cwt. and making sixty 9-inch strokes per minute, through grates having apertures $\frac{1}{8}$ inch in diameter, 24 tons being stamped daily. The slimes pass first into a pit 3·3 feet deep and 9·8 feet in cross section, where the richer material forming the normal ore for the pans is deposited, after which a second collection of poorer stuff is made in a second pit of the same size, and finally the waste, together with that from the pans, is passed through a series of catch-pits 9·8 feet long, 5 feet broad, and 3·3 feet deep.

The reduction of the richer slimes is effected in pan amalgamators of the improved Varney pattern,[1] which perform the three operations of grinding the particles of ore to impalpable mud, mixing the particles with the chloridising agent, and reducing and amalgamating the silver minerals. The pan is essentially a mill, with cast-iron instead of stone grinding surfaces, which is adopted partly from economy and partly from the property possessed by iron of reducing the mercurial chlorides. These surfaces are put together in segments, so as to be easily renewable, as they are worn out in forty days when worked at seventy revolutions per minute. The charge of the pans is 800 pounds of ore stuff from the stamps, which is mixed into a thin mud by adding water and running the pan for half an hour or an hour until the materials are sufficiently ground. During this period a jet of steam is introduced, in order to warm up the contents to 176° F. Chloridising and reducing agents are then added in the following proportions: sulphate of copper, 4 pounds; salt, 40 pounds; and mercury, from 70 to 90 pounds, including $\frac{1}{4}$ pound of zinc amalgam; or about 13 times as much salt, and 32 times as much mercury, as is used in the Mexican or 'patio' process of amalgamation.

[1] Vide *Elements of Metallurgy*, by J. A. Phillips, p. 650 *et seq.* Also Hague and King's *Mines of Nevada*, and Raymond's *Reports*, &c.

The copper salt is added in somewhat larger quantity than would be required for the chlorination of the whole of the silver, assuming it to be effected by cupric chloride. The reactions are considered by the author to be substantially the same as those in the 'patio' process, and as probably occurring in the following order: amalgamation of metallic silver and gold; conversion of cupric sulphate into chloride; conversion of silver sulphide by cupric chloride, with the formation of cupreous chloride, into silver chloride; reduction and amalgamation of the latter by metallic mercury; and, finally, decomposition of the mercurial chlorides formed by the iron of the pan. The zinc amalgam is said to help by the production of electric currents. Like the Mexican process, the method is not well suited for the treatment of minerals containing lead, zinc, or antimony, the working of such ores being attended with a considerable loss of silver and mercury.

The amalgamation process proper requires about four hours, the progress of the operation being controlled by washing out samples of the mud at intervals, and observing the colour and form of the mercury globule obtained, which should be grey, and 'tail,' or assume an oval form.

The finished charge from the pan is received in a cylindrical washing vat, or settler, and allowed to rest for an hour, whereby the bulk of the mercury and amalgam separate from the mud and fall to the bottom. Afterwards the lighter particles are removed through a hole in the side by a stream of water, which flows for fifty minutes; lastly, the bulk of the mercury is separated from the remaining heavy mud charged with ore, by drawing it from a lower opening for ten minutes. As the amalgam is very poor, owing to the large quantity of mercury used, only the excess of the latter introduced at each washing above a large fixed amount is removed in clearing the settler, the whole quantity being only removed at intervals of eight days.

The waste or tailings of the first operation, consisting largely of heavy metallic sulphides, with probably some silver sulphide, and containing about 35 per cent. of the original amount of silver,

are reworked in four large pans or 'tailing mills,' which take charges of double the weight of those worked in the ore-pans, but are otherwise similarly arranged. An assay of this material gave 28 ounces of silver per ton, and appeared by vanning to consist of $\frac{9}{10}$ of quartz and $\frac{1}{10}$ of heavy sulphides, pyrites, blende, and galena. The reagents used per 1,600-pound charge are: salt 40 pounds, sulphate of copper $5\frac{1}{2}$ pounds, and mercury 120 pounds, the latter being about seventy times the weight of the silver in the ore.

The working of the tailings, both in the pans and settlers, is exactly similar to that in the ore mills. The waste from the last washing, containing about 1 ounce to the ton, is passed through a catch-pit before being allowed to run to waste. A further quantity of 20 per cent. of silver is recovered by the second operation, showing the final loss to be about 15 per cent. of that contained in the ore. Allowing four hours for the filling of the tailing tanks, the extraction of the silver from the ore, counting from the first charging of the ore-pan, is effected in sixteen hours. The amalgam collected is treated at intervals by filtration through canvas, after which it is washed in quantities of a few hundredweights at a time in a pan with water to clear it from mechanical impurities, filtered a second time, and finally heated in retorts holding 1,200 pounds. The time required for distillation is from eight to fifteen hours, on account of the great variability in its composition. The sponge silver for the retorts is melted in blacklead crucibles holding 50 pounds and run into bars.

The great advantages of the pan process, as compared with other metallurgical operations, namely, speed and cheapness of work, together with large production from a small plant, are, in the author's opinion, obtained by a considerable waste of silver, which he calculates at 18·7 per cent. of the total quantity, and as due to the effect of the lead and zinc ore. Nearly the whole of the gold is, however, saved. The loss of mercury is 2 pounds per 2,000 pounds of ore treated, or 80 per cent. of the weight of the silver. The staff required is very small. With twelve workmen of all descriptions about 17 tons of ore

are treated per day. The machinery is driven by steam power, the cost of wood for two engines being about 8*l.* daily. The total cost of working, including wages, materials, wear of machinery, &c., is about 2*l.* per ton of ore treated, or about 1*s.* 2*d.* of silver recovered.

The next table, by Mr. A. Trippel,[1] of New York, affords a view of the results and costs of the dry concentration of silver ore at the Manhattan Silver Mill, Nevada:

COPPER.—At the Cape copper mines the costs of extraction and dressing ready for sale during recent years have been as follows:

		s.	*d.*	
Costs inclusive of all charges, carriage to England included, in	1874	10	9	per unit.
" " " "	1875	10	2	"
" " " "	1876	9	10	"
" " " "	1877	8	1	"

Or an average of 9*s.* 8½*d.* per unit on a yearly output of 12,000 tons of 30 per cent. ore. The cost of raising the ore to the surface is 3*s.* 2*d.* per unit, or 4*l.* 15*s.* per ton of ore. In this case it is the high percentage of copper in the ore that enables the mines to be worked at a profit.

Professor Ansted[2] gives the cost of getting the ore at the mines of Boudendach in Algeria at 52*s.* per ton, dressed to a percentage of 16½. The dressing is put at 30*s.* a ton; carriage to Port Tenez, 8*s.*; total, 4*l.* 18*s.*, which, with freight to Swansea, 12*s.*, makes 5*l.* 10*s.* a ton, to which should be added costs of management, &c. At 12*s.* per unit the value in Swansea would be 10*l.* per ton.

At the Parys Mountain Mines in Anglesea, the North Discovery and Carregydol lodes, fig. 55, averaged six to seven tons of copper ore, of about 5 per cent. value per cubic fathom. The ground was hard, and blunted the tools rapidly. The cost of driving was from 9*l.* to 10*l.* per fathom, and the cost of stoping 5*l.* to 6*l.* per cubic fathom. The average cost of getting

[1] *Engineering and Mining Journal of New York.*
[2] *Scenery, Science, and Art.*

1875	Pounds ore reduced	Assay value	Bullion obtained	Value tailings	Bullion and tailings	Amount lost	Average mill test	Per cent. of bullion	Per cent. of tailings	Per cent. of loss	Per cent. of chlorination	Wood consumed	Charcoal consumed	Pan charges	Tons crushed per hour	Cost of milling
		$	$	$	$	$	$					$	$	$		$
January .	1,126,000	100,364 29	87,036 37	10,359 20	97,395 57	2,968 72	178 23	86·72	10·6	2·67	89·8	628	4,800	2,000	1,592	Labour . . 8 68
February .	893,500	78,296 62	70,120 38	7,795 78	77,916 16	380 46	177 93	89·55	10·2	0·24	90	363	3,500	1,787	1,731	Fuel . . . 12 78
March . .	1,236,250	127,602 00	111,087 37	12,387 23	123,474 60	4,127 40	203 20	87·05	10·3	2·64	90·6	528	4,727	1,719	1,816	Supplies . . 2 02
April . .	117,500	116,669 94	106,654 69	9,067 93	115,722 62	947 32	209 94	91·41	7·7	0·884	90·8	483	4,025	1,650	1,839	Quicksilver . 3 03
May . .	966,000	105,277 64	94,613 13	10,413 48	105,026 61	251 03	209 81	89·87	10·2	—	91·6	436	3,840	1,785	1,898	Salt . . . 2 56
June . .	1,167,000	137,087 70	114,997 89	12,965 37	127,963 26	9,124 44	230 04	83·88	9·4	6·71	92·8	453	4,700	1,690	1,885	Office labour 0 92
July . .	1,136,500	130,935 71	111,874 53	11,688 90	123,563 43	7,372 28	227 04	85·44	8·9	5·65	92·3	587	4,964	1,716	1,800	Castings . . 0 83
August .	959,500	94,384 64	81,935 72	9,105 75	91,041 47	3,343 17	196 12	86·81	9·7	3·48	91·8	461	4,931	1,586	1,719	Hauling . . 0 90
September	1,120,750	110,256 54	96,907 49	10,495 82	107,403 31	2,853 23	198 07	87·89	9·7	2·40	91·5	463	5,400	1,729	1,916	
October .	1,255,750	139,871 26	120,435 49	10,868 49	131,303 98	8,567 28	221 35	87·03	8·4	4·56	93·8	458	6,300	1,794	2,137	$31 72
November	1,094,500	110,401 10	96,178 62	9,303 25	105,481 87	4,919 23	208 01	87·11	8·8	4·08	92·6	413	5,230	1,852	2,130	
December	1,176,500	122,818 20	112,812 50	8,970 81	121,783 31	1,034 89	205 78	91·85	7·7	0·44	94	451	5,100	1,761	1,890	
Totals and averages	12,249,750		1,204,654 18					87·67			91·8					

the ore out of the mine was from 5*s*. 6*d*. to 7*s*. per unit. The dressing cost from 5*s*. to 6*s*. per unit, to which, if we add costs of management and renewals, the ore would cost from 10*s*. 6*d*. to 11*s*. per unit.

At the Lake Superior Copper Mines the cost of raising 'stamp work'—the middle quality of the ores—at the Hogan Mine, inclusive of all operations necessary for preparing the ore for market, after the mine had been laid open for stoping, was, some years since, as follows:

	Per ton
Stoping	$2 00
Filling, landing, and wheeling	0 26
Tramming to kilns	0 06½
Burning, including wood and labour	0 35
Dressing	0 68½
Steam engine and labour at stamps	0 76
Miscellaneous charges, carpenter, smith, &c.	0 30
	$4 42

The stamp work is reckoned to produce 90 per cent. of pure metal.

The production of metallic copper from the whole of the workings of the Hogan and Stourtenburgh Mines was approximately 225 lbs. per fathom.

TIN.—The following particulars of prices paid for general mining work in Cornwall are partly applicable to mining for copper.

The sizes of shafts in the county are from 5 to 15 feet long, by 3 to 5 feet wide. The prices paid for sinking shafts are:

	£		£	
In soft clay slate, to a depth of 20 fathoms from surface	2	to	3	per fathom
,, ,, below this depth	3	to	4	,,
In hard clay slate, to a depth of 20 fathoms	4	to	6	,,
,, ,, below this depth	5	to	8	,,
Where powder is used, or in ordinary blasting ground, to a depth of 20 fathoms	6	to	8	,,
,, ,, below this depth	10	to	30	,,
In extreme cases of hardness	70	to	80	,,

Driving levels, about two-thirds of the preceding prices. Smaller levels in easy ground are driven at from 8s. to 12s. per fathom forward.

Stoping costs about two-fifths of the price of driving levels.

Average cost of breaking and selecting the ore, and sending it to the surface, 4s. to 8s. per ton.

The eight mines named below gave, in 1866, the following proportions of black tin to the ton of ore raised:

	lbs.		lbs.
Huel Kitty	84	East Carn Brea	18
Dolcoath	56	Polberro Consols	14
Tin Croft	35	Huel Coates	6
Huel Uny	23	Llanwit	4

At St. Ives Consols as much as 1,344 lbs. have been obtained to the ton of ore, but the average was only 45 lbs.

In 1856, of thirty-two of the best mines the highest average was given by Huelvor, which gave 144 lbs. to the ton of ore.

The present percentage of black tin derived from all the tin ore sent through the stamps and dressing floors of Cornwall is estimated at 2 per cent., or nearly 45 lbs. to the ton of ore.

In 1877, 14,142 tons of black tin gave 9,500 tons of metallic tin. It may be taken, therefore, that 100 lbs. of black tin yields about 70 lbs. of metallic or block tin.

The cost of mining and preparing tin ore for the market has decreased during recent years at the best mines from 52*l.* to 27*l.* per ton. Possibly 35*l.* may more nearly represent what at present may be considered the lowest average price as spread over a number of the best mines.

Fifty tons of ore will ordinarily have to be mined to produce one ton of black tin. If we put the cost of stoping per fathom at 3*l.*, and take four square fathoms of a lode 4 feet wide as equal to 50 tons, this would give 12*l.* The cost of dressing, from the pit's mouth to the ore bin, varies from 5*l.* to 12*l.*, but 9*l.* is taken as the average; this would make 21*l.* Then come dues, cost of management, pumping, and renewals,

so that we cannot at present reckon upon a much less cost than 35*l.* per ton.

At the stockwerk of Altenberg, Saxony, fig. 66, the whole mass is quarried, stamped, and washed; the proportion of black tin being 2 per cent. of the whole.

At the alluvial tin mines of Banca, a workman, in a day of nine hours, removes, with the aid of water, from 350 to 530 cubic feet of earth. The top ground is dug off and removed, and then a stream of water turned on. Bowls, launders, and strips or strakes, are used for intercepting the tin, as in alluvial gold mining. The experienced labourers receive 1*l.* per month and their board. The new-comers only receive 13*s.* 4*d.* and their board. The quantity of earth removed yearly for each person of all sorts at a mine is estimated at about 12,000 cubic feet; the yearly yield of metallic tin for each employé of all kinds being 12 cwt.

In Australia, in washing for stream tin, a man is said to handle, or pass through his hands, 10 tons of earth a day.

In Cornwall, in 1876, 800 persons of all sorts were employed in alluvial tin mining on the Red River. The production of tin ore amounted in value to 18,460*l.*, and the average earnings to 10*s.* a week.

LEAD.—At the Van Mines at the present time the cost of stoping ranges from 40*s.* to 80*s.* per fathom. In Cardiganshire and Carnarvonshire the prices range higher, as they also do in lodes in the limestone districts. The cost of driving is nearly double this price. The cost of sinking winzes about the same —of *rising*, or working a winze or a shaft upwards, about one-half more.

The paying lead mines contain from 25 cwt. to 3 tons of ore per fathom, with varying quantities of blende. There is not as yet, I think, an instance of a lead mine paying on an average production of less than 25 cwt. per fathom, but there ought to be many. In an ordinary mine, in which from one-half to two-thirds of the area of the lode contains ore, the cost of stoping may be roughly taken at about one-third of the total cost of the ore when prepared ready for sale: one-third being

apportioned to development and exploration, and the other third to pumping, general expenses, and management. A rib of lead one inch wide in a lode represents 10 to 12 cwt. per fathom.

In Carnarvonshire the hand-dressing of lead costs from 18*s*. to 20*s*. per ton; but, by machine-dressing, it is done at an average cost of 13*s*. per ton.

At the Flintshire Lead Mines, worked in lodes, the cost of dressing is put at about 16*s*. per ton.

At the North Hendre Lead Mine, which is worked in a 'flat' lode or bed, fig. 97, the prices paid are: for raising lead, 20*s*. per ton; for tramming the same a distance of 300 yards, 16*s*. per 20 tons; for dressing the ore—most of it being in lumps—ready for sale, 9*s*. per ton; for driving levels in limestone 3*l*. 10*s*. per yard.

ZINC.—This metal is, as we have seen, closely associated with lead ores. The cost of dressing the ore at the Flintshire mines is from 11*s*. to 16*s*. per ton.

Mr. E. Gybbon Spilsburg[1] gives the following table of the cost of zinc extraction at the Lancaster County Zinc Mines, Philadelphia:

Cost of mining 40 tons of ore a day at $1 00	$40 00
Transportation to dressing floors	2 00
Dressing 40 tons, loss in weight $\frac{1}{3}$ = 26·63 tons dressed	20 00
Two engineers at $1 50	3 00
Two tons of hard coal at $2 38	4 76
Labour in roasting 26·63 tons at $1 00 per ton	26 63
Fuel, 26·63 tons at $4 00	106 52
Labour to reduce, say 24 tons calcined ore, say 18 shifts, at $9 00 per shift	162 00
Fuel for reduction in furnaces, 25 tons at $2 38	59 50
Fuel used for reduction in retorts, 7½ tons at $1 50	11 25
Retorts used, 54 at 75c.	40 50
Condensers used, 180 at 2c.	3 60
	$479 76
Ten per cent. of above for wear and tear and general management.	47 98
	$527 74

Zinc produced would be at lowest possible estimate 9,900 lbs.

[1] *Engineering and Mining Journal*, New York, July 1877.

Dividing the above cost by this number of pounds would give under 3 cents as cost of zinc per pound. The following analysis shows the quality of the spelter produced:

Zinc	99·687
Cadmium	·034
Lead	·262
Copper	Trace
Iron	·017
	99·998

The following account of the zinc mines on the Schneeberg, Tyrol. will also be of interest:[1]

These mines, amongst the most elevated in Europe, were formerly wrought for argentiferous lead ores, having in 1486 employed 1,000 men. In 1866 they were reopened, and it was determined to utilise the large discoveries of zinc-blende which, together with some galena and a little copper pyrites, form the bulk of the metallic contents of the lodes. These lodes are from 7 to 56 feet thick, and have been proved in direction for a distance of about 1½ mile, and by the outcrops in depth to more than 2,700 feet. The chief point of interest is in the great differences of level that have to be overcome in the transport of the mineral from the mines to the dressing floors and smelting works across intervening mountain ridges. The St. Martin, or principal working level, lies 7,763 feet above the sea level, and there are numerous workings above and below this point. The Kaindl tunnel, by which a principal ridge is crossed, lies at an altitude of 8,262 feet. The principal arrangement of the roads in this very broken system of transport are the following:—A lift 1,459 feet long, 623 feet vertical height, rising on the ridge above the Passeyer Valley, connects, by a railway 2,079 feet long, with a second lift, 2,735 feet long and 465 feet rise, with one end of the Kaindl tunnel. This is 4,211 feet long, and crosses the ridge to the Lazacher Valley. From this

[1] From James Forrest's *Abstracts of Papers in Foreign Transactions and Periodicals*, for the Proceedings of the Institution of Civil Engineers.

point the road is all downhill, commencing with an inclined plane 2,332 feet long and 1,125 feet fall, to a cart-road about 3½ miles long, on a gradient of 1 in 11, leading to Meiern, where there is a second inclined plane 846 feet long, and 479 feet fall, at the bottom of which new and large dressing floors are in course of erection. From the new dressing floors a road of 5 miles, on a gradient of 1 in 135, leads to a third inclined plane, 1,430 and 479 feet fall, to a point on the road to Sterzing, about 3¾ miles distant from the railway station. From this it appears that the stuff from the mine travels first uphill about 1,100 feet for about 1¼ mile to the summit, thence about 3,240 feet down in 5 miles to the dressing floors. The farther distance to the station is nearly 10 miles.

A portion of the ore, that containing lead, is dressed at the mines; the works, which from their altitude can only be used during four months of the year, include forty heads of stamps, eight V-channel classifiers (*spitzlutten*), two spitzkasten, eight percussion and jagging sieves, and ten double Rittinger percussion tables, the power being supplied by an overshot wheel driven by the water of the Schwarzensee, a lake 7,400 feet above the sea level. The lower works at Meiern, which are available during nine months in the year, are divided into two parts: that for the coarser mineral, containing Blake crushers, picking tables, sizing drums, and coarse jiggers, is driven by a water-pressure engine, on Mayer's principle; the second, for the finer sizes, driven by a Girard turbine, contains 20 heads of stamps and ten double percussion tables, besides the necessary centrifugal pump elevators and slime pits; a third portion, containing the crushing rolls, is not yet erected. In their present condition the mines are equal to an annual production of 2,500 to 3,000 tons of blende in lumps, and 4,200 to 4,500 tons in various dressed sizes, averaging 42 to 45 per cent. produce for zinc, and 320 tons of dressed lead ore, but when the machinery and road are completed these quantities will be increased threefold.

IRON.—The costs of working the Clay-Band ironstone of the Warwickshire coalfield in the years 1874–5 was:

	s.	d.	
Getting and filling	5	3	per ton
Hauling and laying . . .	0	7	,,
Overlooking and repairing . .	0	7	,,
	6	5	,,

The ore was sold at 11*s.* 6*d.* per ton delivered in trucks at the colliery.

The costs of working the mainband of the Cleveland ironstone is approximately 10*d.* to 1*s.* 3*d.* per ton, apart from management and outside expenses.

It is said that Spanish hæmatites of 60 per cent. strength can be delivered free in Philadelphia for 33*s.* per ton.

I conclude this chapter of statistics with a list of the deepest mines in the principal countries of the world, as compiled by Mr. W. Rowley, F.G.S., of Leeds,[1] which also includes the deepest shafts of coal mines:

	Country	Name of mine	District	Mineral worked	Depth, yards
1	Austria	Adalbert	Birkenberg	Silver and Lead	1,093
2	Belgium	Viviers	Gilly	Coal	940
3	Saxony		Zwickaw	Coal	879
4	Prussia	Samon	St. Andre	Silver	844
5	Great Britain	Rosebridge	Wigan	Coal	814
6	Norway		Kongsberg	Silver	623
7	Hungary	Amalia	Schmeritz	Gold and Silver	590
8	Prussia	Camphausen	Saarbruck	Coal	550
9	Spain	La Luerti	Canada	Silver	516
10	Italy	Monte Masio	Gavarrono	Lignite	481
11	Sweden	Bersbo		Copper	459
12	Pays-bas (?)	Whilhelm	Kerkrade	Coal	364
13	Baden		Hagenback	Coal	360
14	Portugal	Taylor	Palhal	Copper	359
15	Bavaria	Max	Stockholm	Coal	286
16	Russia	Turjinsk		Copper	202

To the above may be added the Snailbeach Lead Mine. Shropshire, which is now 463 yards deep.

[1] *Mining Journal*, October 28, 1876.

CHAPTER XLI.

GENERAL CONSIDERATIONS.

Large Proportion of Unprofitable Mines—Unsuccessful British Mining in America—Causes—Want of Knowledge of First Principles—Insufficient Capital—Excess of Unproductive Capital—Exorbitant Prices paid for Mines—Expensive General Management—Ditto Local Management—Mine Gambling—Rules to Regulate the Sale and Purchase of Mines—Possible Reduction in the Cost of Working Mines—Remedies—Possible Future of Successful Mining—Concluding Observations.

ADMITTING, as I think we must, now that we are approaching the end of our inquiries, the great scientific and mechanical interest attaching to metalliferous mines and mining, it is humiliating to have to confess that the majority of mining enterprises are commercial failures.

It is still more humiliating to be obliged to admit that this confession applies with particular force to mining in the British Isles, and the more so, since, for their size, these islands are the most highly mineralised portion of the earth's surface. A larger proportion of mines pay, as far as can be ascertained, for working, in America and in Germany; and the worst of it is, that, as a rule, the most unsuccessful mines in North-Western America are those worked by English companies and under English management. It is said that of American mines introduced into this country within the last seven years, all but one or two have been failures, and have entailed a loss of money amounting to 10,000,000*l.*

Then there are between 500 and 600 lead mines in this country, of which scarcely fifty are paying a profit. There are 104 copper mines, making returns of ore, of which, I do not think, more than a dozen are worked profitably. Indeed, we

may safely assume that the proportion of unprofitable to profitáble mines is ten to one.

This is a serious state of things, and one that almost amounts to a national disgrace, and it behoves us to seriously consider whether it arises from unavoidable difficulties, inherent in mining, or whether any part of the cause of failure may be moved.

Mining is, at the best, an adventurous business, and, as such, it is a business for energetic and adventurous men, born explorers, who have time or money, or both, to spare. Happily, there are plenty such.

If my readers have followed this book closely, they must, I think, have come with me to the conclusion that mining need not be such a risky business as it is, and that the disproportionate number of unsuccessful mines may be considerably reduced. For, first, there are a good many such mines that, hitherto from want of knowledge, have been opened in strata where there can be little or no prospect of success. I know of many such—lead mines, for example—whose explorations are now being pushed forward in the soft black Lingula Flags below, and in the unproductive Bala beds above, the Llandeilo lead strata. One case occurs to me, where a 'lead mine' has been struggling for years in the Wenlock Shale of North Wales, the discovery of an occasional string or bunch of galena enabling the explorers to defy the geologists.

Numbers of mines, too, in limestone districts are being unsuccessfully worked in shale, grit beds, and the unproductive dark limestone beds. Here, then, is a large class of mines which are unsuccessful on account of the ignorance of their promoters and managers of the first principles governing the accumulation of ore deposits.

The same ignorance has, I fear, often led to the loss of much money in unwise explorations in the known productive horizons of ore.

There are mines also that owe their abandonment to want of sufficient capital. The costs and possible requirements of the undertaking had not been carefully considered in the first

distance. It is the old story, oft repeated, of 'beginning to build, and not being able to finish.' The result has been inadequate machinery to cope with the water, the expenditure of what money there was in an endeavour after immediate surface results, an inability to pay the rent, and the lapse of the lease; and in some mines of real worth a sum of money being paid yearly for bank commission and interest that of itself would pay a moderate dividend on the capital actually necessary for the establishment of the mine. To mining readers more than one Cornish mine will afford illustrations of this.

Another group of unsuccessful mines owe their failure to a mistake in an opposite direction to the last, which is the overloading of the mine with unnecessary and unproductive capital. Sums of from 10,000*l.* to 70,000*l.* are asked and paid for mines which a few moments of ordinary business thought will show could not at the best ever pay a mining profit on more than one-fourth of the sum, to say nothing of the additional capital required for working them. The misfortune is, that the very great success of one or two mines in a country, like the richness of one or two prizes in a lottery, throw a glamour and haze over the minds of the people who invest in such undertakings, and who, unfortunately, are usually people of limited means, who are eager to become rich, or to increase their scanty means.

The last-named group of unsuccessful mines is closely associated with another group, which is ruined by expensive management and working. If we imagine a company formed in London, with a lord for its chairman, and a general and a colonel among its directors, with a managing director, a secretary, and a consulting referee, in order to manage and carry on an ordinary grocery business in a small country town, we have supposed something that is not a whit more ridiculous than are the confederations frequently established to work good little mines which, at the most, cannot yield more than the profits of a grocery business. These mines, and there are numbers of them, would pay a moderate profit to a limited local partnership, but the little profit is more than swamped by the remuneration and travelling expenses of directors, secretary, engineers,

and the like. Happily, we find many such mines paying such local partnerships, especially where one of the owners resides or is often at the mine.

The baneful influence of the two last causes extends to the local management of the mines. The mine is worked and the reports are made too often, it is to be feared, with a view to the 'bull' and 'bear' operations on the stock market, and often with a view to the money to be made, or the greater share in the mine to be secured by a reconstruction or a refloating of the company, after a preliminary winding-up.

The fact, too, that more money is made in good times by floating such mines than by working them, induces a gambling and reckless spirit among all the officials, and, it may be, among the miners at a mine.

It will also be found that at mines which have been dearly paid for, and are expensively managed, the prices paid for driving, sinking, stoping, and for most work out of sight, average higher under equal conditions than do those paid at mines worked for business profit under careful personal management.

Turning to foreign mines worked by Englishmen we see a few which, from their extraordinary riches, do pay. The remainder suffer from the causes already enumerated. They also suffer from others. Most British mines in America, for example, suffer from litigation. 'Jumpers,' as they are called, set up prior claims, and as in the newly settled countries they and their class form the courts, and sometimes supply the judges, the verdict usually goes against the stranger.

Then there are the questions of boundary, which are ever cropping up, for, as the United States mining law allows a lessee to follow the lode downwards wherever it leads, in doing so he often gets into other people's property. And then there is the question, 'What is a lode?' An American court, for example, has recently decided in the dispute between the Eureka (an American) and the Richmond (a British company) that the mass of mineralised limestone of Ruby Hill (fig. 41), a mass nearly as thick as the mass of our Northumberland or Denbigh-

shire limestone, is a lode! Of course, in such an unsatisfactory condition of the law, there can be no security for investors.

Then it must be confessed that the English management of mines in Western North America has been far inferior to that of the Americans of their own mines.

We have often sent abroad mine managers, who, good enough in Cornwall, knew nothing of the different conditions of the ore deposits there. Well-intentioned and intelligent, too, as many of them were, they were under the direction of incompetent men, whose chief qualification for the post of general manager or managing director seems to have been that they had failed in everything else. If to all this we add the essential difficulties of mining, the distances to travel, the cost of carriage of materials, the temptation to agents to be careless and neglectful, and of workmen to skulk and be idle, we gain an idea of the difficulties that lie in the way of successful mining at a great distance from the seat of its direction.

On the purchase and sale of mines.—The reference just made to the extravagant prices paid for mines and mining properties naturally leads to a consideration of the principles that should regulate the purchase and sale of the same. I would here lay down two axioms—1st. *They who take the risk are entitled to the profits of success;* and, 2nd. *Where nothing has been discovered that can be profitably worked, there is nothing to pay for.* The opinions of engineers or other mining authorities, however eminent, or practical, or experienced; the parallelism or the continuation of a good lode, or the proximity of a property to a successful mine, whose chimneys can be seen—a ground of recommendation given in a recent prospectus—are matters which should be duly considered by a man or a company who propose to spend money in exploring further, but they are not things to pay a premium of thousands of pounds for.

Some of the first questions to be asked by an intending purchaser should be—What proportion of the purchase-money will the ore now actually discovered, if it can be worked to a profit, pay? and, what amount of ore will have to be raised,

and number of fathoms of ground cut away, before the amount of the purchase-money can be recouped, less the valuation price of the plant?

Now, supposing a lead lode is discovered that yields on an average 25 cwts. of ore per fathom to the usual proportion of productive ground, we can hardly, in the present state of mining, calculate upon a greater profit than 2*l.* per fathom of ground cut, at an average selling price of 10*l.* 10*s.* per ton. If a copper lode worth 4 tons of ore of 6 per cent. quality is discovered, we cannot reckon upon a larger profit than 2*l.* per fathom (if we can as much), at a selling price of 12*s.* per unit. Now, in each of these cases, for every 1,000*l.* of purchase-money paid, 500 fathoms of the lode will have to be cut down. If the purchase money amounted to 70,000*l.*, as in a recent sale of a copper mine it did, no less than 35,000 fathoms of the lode would have to be extracted before the purchase-money could be repaid. If the profit could be estimated at 3*l.* per fathom, then 330 fathoms, if at 4*l.* per fathom, 250 fathoms of the lode would go to pay each 1,000*l.* of the purchase-money.

An original discoverer should, of course, be remunerated for his trouble, intelligence, and expense in making such discovery. The fairest way to do this is by giving him a share in the future success of the mine. If we double the actual cost he has incurred, always supposing the money has been judiciously expended, then whatever proportion this augmented sum bears to the capital actually required for the working of the mine should, I think, determine the amount of share he is entitled to. For example, if he has actually spent 500*l.*, we double it for him on account of the risk he first incurred, making 1,000*l.* If the capital of the mine is ultimately 5,000*l.*, he is entitled to one-fifth share. This rule, which to me appears fair, may be readily applied to larger transactions.

But a vendor or vendors should not be allowed to throw their shares on the market, except by special arrangement, until the mine pays its cost.

In the case of the transfer of a mine in full work, and paying an annual income, the price to be paid should not, I think,

exceed five years' purchase, added to the valuation price of the plant. Thus, if a mine is returning a clear income of 2,000*l.* a year, its price should not exceed 10,000*l.*, added to the price of the plant as valued for transfer.

If we look at the mine reports which appear in the mining papers we shall observe a large number of mines whose stopes are worth from 15 to 25 cwts. of lead ore per fathom, with, perhaps, a little blende, and which do not pay. I feel little hesitation in saying that they ought to pay a modest profit on the capital actually necessary for their development and working. For example, take an average of one ton of ore per fathom, worth 10*l.* 10*s.*, taking one time with another; let there be the ordinary quantity of barren ground; pay 50*s.* per fathom for stoping; add 50*s.* more for development; add 50*s.* for dressing and for management; this makes 7*l.* 10*s*; put the cost, if we will, at 8*l.* 10*s.*, and it will be seen that when the mines are opened such mines ought to pay.

The sources of failure I have indicated naturally suggest their remedies. We want a more intelligent class of miners—I mean in their own business. Why should not every elementary school in a mining district have a section of the ground below, with its lodes and mineral zones defined on it, hung on the walls? Can we not spare some of the general knowledge required in our school standards, or in the 'special subjects,' for the sake of local technical knowledge?

We want, also, a more intelligent race of mine captains and engineers. I feel ashamed, sometimes, when I think how German mining engineers may read the reports of some of our mine captains and experts on mineral properties. Still, great advances have been made of late years, and with more field and underground work, added to the teaching of our schools of mines and local mining schools, we should soon take what we ought to aspire to—the front rank as miners.

Then we want ordinary business principles and honesty applied to the outside management of mines and to their purchase.

These requisites are surely attainable, and they would, as

we have seen, alter very materially the proportion of profitable to unprofitable mines.

Then a further reduction in the cost of mining may be made by new explosives, by rock drills, and by improved pumping and dressing machinery. Thus, the cost of the production of tin in Cornwall has been reduced by quite one-fourth of late years, at the best mines. The same reduction may be made in the cost of lead and copper. If it is made, and it can and must be made if we are to compete with other nations, we have many years of increased mining prosperity before us.

I would emphasise what I have already said, that mining is a business for the strong, the adventurous, and for the men who can spare money, without the possible loss of it hurting them. No one is justified in investing in mines the source of a scanty income, or money that is needed in his own business. If such people lose their money they have themselves alone to blame. For the others, it is a pursuit of pleasurable excitement, of intelligent activity, of ample scope for inventive genius, and of at least ordinary chances of success. It is an honourable pursuit; for he who wins the 'precious things of the everlasting hills' fulfils no common part in the economy of the world.

GLOSSARY

OF WORDS AND TERMS USED IN MINING, AND OF SCIENTIFIC WORDS USED IN THIS BOOK.

Abbreviations. — *Am.*, *American*; *Aus.*, *Australian*; *C.*, *Cornish*; *D.*, *Derbyshire*; *F.*, *French*; *G.*, *German*; *N.*, *North of England*; *S.*, *Spanish*; *W.*, *Welsh*.

ABBRUCH. *G.* Ore broken off the lode or deposit.

ABENDORT. *G.* The end of a mine towards the setting sun.

ABENDSCHICHT. *G.* Afternoon shift or company of miners.

ABENDSTOSS. *G.* The western end of a mine.

ABFÜLLEN. *G.* To draw off a good body of ore.

ABFLANHERD. *G.* A buddle.

ABKOMNISS. *G.* The junction of a tributary with a main lode.

ABRA. *S.* A hollow, opening, or fissure on a lode.

ABRONZIADO. *S.* Yellow copper ore, sulphides.

ACCOMPT. *C.* Account day, the usual settling day; the place of meeting, or account house.

ACHICAR. *S.* Term expressing the decrease of water in a mine.

ACICULAR. Needle-shaped.

ADEMAR. *S.* To timber.

ADEMADOR. *S.* A timberer, or mine carpenter.

ADIT. A level driven in the side of a hill, and opening out into daylight.

ADDLINGS. *N.* Earnings.

ADULARIA. A hard translucent variety of felspar containing much orthoclase. See 'Orthoclase,' also 'Felspar.'

ADVENTURE. *C.* A mining enterprise, a trial.

ADVENTURERS. The original promoters or speculators in a mining trial.

AHONDAR. *S.* To sink.

AIR MACHINE. A machine for creating ventilation in mines.

AIR PIPES. Pipes of metal or wood for the conveyance of air.

AIR STACK. A chimney built for ventilation.

AITCH PIPES. The parts of a pump-lift in which the valves are fixed.

ALBAÑIL. *S.* Mason.

ALBAYALDE. *S.* White lead.

ALCAM. *W.* Tin.

ALIVE. *C.* The productive part of a lode is said to be alive.

ALLUVIUM. The mud, silt, and gravel deposited by rivers and floods.

ALMADENETA. *S.* A stamp head.

ALMAGRA. *S.* Red ochre.

AMALGAM. The compound of mercury with gold or silver.

AMMONIA (Muriate of). Chemical composition, ammonium 33·7, chlorine 66·3.

AMYGDALOID. The name given to igneous and metamorphic rocks having almond-shaped substances distributed throughout them.

ANTICLINAL. When strata dip away from each other, as in fig. 89, they are said to be anticlinal.

ARENACEOUS. Sandy.

ARGILLACEOUS. Clayey.

ARIAN. *W.* Silver.

ARRAGE. *N.* Sharp point or corner.

ARRAGONITE. Needle spar, carbonate of lime mixed with 0·1 to 4 of carbonate of strontia.

ARRASTRAR. *S.* When veins unite or are drawn together.

ARRASTRE. *S.* An appliance for arresting the particles of gold and other ores in the process of washing.

ARROBA. *S.* A Spanish weight = 25 lbs.

ASBESTOS. A fine elastic fibrous variety of hornblende, in colour ranging white, grey, and green.

ASH. The name by which igneous, eruptive, and metamorphic rocks are known when they are of an ashy or cindery nature.

ASPIRAIL. *F.* An opening for ventilation.

ASTYLLEN. *C.* A small dam in an adit; a partition between ore and leads on the grass.

ATTAL, ADDLE. *C.* Valueless refuse filling old mines; stony matter about ores.

AUGITE. Chemical composition, silica 56·36, lime 25·46, magnesia 18·18, varied by small portions of the protoxides of iron and manganese.

AUR. *W.* Gold.

AURIFEROUS. Containing gold.

AUSSCHAREN. *G.* The junction of lodes.

AUSZIMMERN. *G.* Timbering.

AXIS. The central part of an anticlinal, as at figs. 37 and 89.

BACK of a lode, the portion of a lode lying between a level driven in a lode and the surface.

BACKING. The timbers fixed across the top of a level, let into notches cut in the rock.

BACK-SHIFT. The second or afternoon set of miners.

BAL. *C.* Commonly a mine. Strictly the outside of a mine, especially when located on a hill.

BALLAND. *D.* Finely separated lead ore.

BANCOS. *S.* Rocks crossing a lode, or diverting it from its ordinary course.

BANK CLAIM. *Aus.* A mining right situated on the bank of a stream.

BANK RIGHT. *Aus.* The right to divert water to a bank claim.

BAR. A band of hard stone or rock crossing a lode.

BARGAIN. A portion of a mine let to a gang of miners to work at a price agreed upon.

BAR MASTER. *D.* The Derbyshire name for a mine manager, agent, and engineer in one.

BAR-MOTE. *D.* A court where matters relative to mines are tried or considered.

BARRANCA. *S.* A ravine.

BARYTO-CALCITE. A mixture of carbonate of baryta and carbonate of lime—occurs as yellowish white transparent crystals.

BASALT. A mixture of augite and felspar with some iron. A dark green or black stone occurring in large crystals or columns, like those of the Giant's Causeway.

BASSET. The outcrop on the surface of a lode or bed.

BEAT. *C.* To stope or cut away a lode.

BED-CLAIM. *Aus.* A mining claim lying on the bed of a stream.

BED-ROCK. *Aus.* The strata immediately underlying loose or drifted matter.

BEN. *C.* Alive. The live or productive part of a lode.

BEN-HEYL. *C.* A live stream, where tin is found.

BINDER. *C.* The underground carpenter who binds or secures the mine.

BING-ORE. *D.* Lead ore in small lumps or cobbles.

BLACK JACK. An ore of sulphide of zinc, blende—mock lead.

BLACK SAND. *Aus.* The name given to black tin, iron, manganese, and other ores usually accompanying gold.

BLACK TIN. *C.* Dressed tin ore.

BLANKET-TABLE or STRAKE. *Aus.* A sloping board or table covered with green baize for the purpose of intercepting gold.

BLIND CREEK. *Aus.* A creek dry except in wet weather.

BLOCK CLAIM. *Aus.* A square mining claim defined by posts.

BLOCKING OUT. *Aus.* Washing auriferous drift in square blocks.

BLUE ELVAN. *C.* Greenstone.

BLUE-JOHN. *D.* Fluorspar.

BOCA. *S.* Mouth of a mine.

BOCAMMA. *S.* Mine opening.

BOLSA. *S.* Name given to a small bunch of ore.

BONANZA. *S.* (Prosperity). Name given to large deposits of good ore.

BONZE. Undressed lead ore.

BORRASCA. *S.* Adversity; name given to a mine when in an unproductive state.

BOTRYOIDAL. Rock showing the structure or appearance of that of a bunch of grapes.

BOUNDER. *C.* The owner of a small patch of ground called a 'bound.'

BRACE. *C.* The ground and buildings around the principal shaft of a mine.

BRANCH. Small string of ore connected with the main lode.

BRAZIL. *N.* Iron pyrites.

BRECCIA. Rock composed of angular fragments of rock cemented together.

BROOCH. *C.* A mixture of various ores.

BROWN SPAR. A variety of dolomite made up of carbonate of lime, carbonate of magnesia, and from 10 to 20 per cent. of carbonate of iron.

BRYLE. Surface indications of a lode, in decomposed mineral matter.

BUCKING. Breaking ore—with a flat iron fixed on the end of a stick—ready for the jiggers.

BUNCH. A small rich deposit of ore.

BUNDING. A staging of wood over a level or road in a mine on which rubbish from the stopes is thrown.

BUNNEY. A pocket or considerable mass of ore not lying in a regular vein.

BURROW. A heap of deads or refuse on the surface.

BUSCONES. *S.* Miners who work on tribute, explorers for minerals, workers of old mines.

CAL or GAL. *C.* A hard rusty-coloured stone containing iron, found in poor lodes. (Welsh, *caled*, hard.)

CALCITE. Calcareous spar, carbonate of lime; chemical composition, lime 56·0, carbonic acid, 44·0.

CALLYS. *C.* Killas applied to the slaty stratified rocks traversed by lodes.

CAM. A long curved tooth fixed on a shaft for the purpose of raising a stamp. (Welsh, *cam* = crooked.)

CANK. *D.* Whinstone, or band of hard rock.

CAÑON. *S.* A deep valley.

CAPLE. *C.* A hard stone lining the sides of tin lodes.

CAPTAIN. The overseer or practical manager of a mine.

CARAT. Term used for denoting the quality of gold. English standard gold contains 22-24ths of pure gold.

CARBONACEOUS. Containing carbon in the shape of vegetable remains.

CARBONATE OF BARYTA. Chemical composition, baryta 77·7, carbonic acid 22·3.

CARBONATE OF STRONTIA. Chemical composition, strontium 70·2, carbonic acid 29·8; occurs as resinous fibres with a radiated structure.

CARBONIC ACID. Chemical composition, carbon 27·65, oxygen 72·35.

CARBONIFEROUS. Containing carbon, as Carboniferous Limestone.

CARGA. *S.* A mule's load = 380 lbs. Spanish.

CARN. In ancient British a monument, a heap of stones.

CARREG, CRAIG. *W.* Rock.

CASCAHLO. *S.* On a mountain applied to stony strata.

CASES. *C.* Fissures through which water runs into a mine.

CAST AFTER CAST. *C.* Throwing up ore from one stage to another in an excavation.

CATEAR. *S.* To search for minerals.

CAUNTER. *C.* Contra, a smaller lode running diagonally across the main lode of a mine.

CAXO. *S.* A measure of ore containing at Potosi 5,000 lbs.

CEFN CEFFYL. *W.* A hump on one of the walls of a lode, nearly cutting off the ore.

CELLULAR. Containing numerous cells or cavities.

CENTNER. *G.* The hundredth part of anything.

CHAPAS. Iron blocks holding the ore inside the stamps.

CHERT. A mixture of fine silica or sand with a portion of lime, and occurring in a hardened form. See 'Hornstone.'

CHLORITE. Chemical composition, silica 32·2, alumina 18·3, magnesia 35·7, water 13·8, varied with small proportions of iron

CLAVOS. *S.* Masses of ore, and of native metals.

CLEET. *D.* A wedge.

COB. *C.* To bruise or break ore into 'cobbles' or small lumps.

COCKLE. *C.* A dark-coloured earthy mineral, like tin, but worthless, and disappointing from its resemblance to the true mineral.

COFFIN. *C.* Name given to old open excavations.

COLORADOS. *S.* Red ores, coloured with oxide of iron, like gossan.

CONGLOMERATE. Rock composed of rounded and water-worn stones cemented together.

CORALLINE. Partaking of the structure of corals; coralline limestone.

CORUNDUM. One of the precious stones, composed of alumina, with peroxide of iron, or other colouring matter.

CORVE. A small waggon used for drawing minerals underground.

COSTEAN. *C.* (*cothas*, find, *stean*, tin). To costean is to search for a lode by sinking small pits along its course on the surface.

COUNTRY. *C.* The strata through which the lodes traverse, or in which ore deposits are found.

COURSE. *C.* 1. Vein or lode. 2. Direction taken.

CRAB HOLE. Bay of Biscay country. *Aus.* Holes, apparently water-worn, met with in the bed rock under the drift, which are often the cause of fatal accidents.

CRADLE. *Aus.* A wooden box used in gold washing, as already described.

CREAZES. *C.* Name given to portions of ore in buddles.

CREEK. *Aus.* Small gully or brook feeding a river.

CROP. *C.* Name given to tin ore when dressed. The finest black tin is called crop, and its value is computed at one half that of the finest grain tin.

CROSS COURSE. A cross vein.

CROSSES AND HOLES. *D.* In Derbyshire the discoverer of a lode secures it temporarily by making crosses and holes in the ground.

CROSS-CUT. A level or tunnel driven towards a lode at right angles to its course.

CRYSTALLINE. Greek (*Krustallos*, ice). The name given (1) to substances when crystallized into definite shapes as described on page 3. (2) As used to describe the internal structure which crystallized substances show on being broken. Loaf sugar, for example, has a crystalline texture.

CUT. To cut a lode is to intersect it at a right angle to its course.

CWLWM. *W.* A band or pillar of rock, cutting off the lode.

DAM. *D.* A barrier to keep back bad air or water.

DAMP. Bad air—choke damp, fire damp.

DAN. A tub or corve without wheels; a sledge.

DAY. Near the surface, where daylight penetrates.

DEAD GROUND. Parts of a lode without ore.

DEAD MEN'S GRAVES. *Aus.* Humps in the basaltic rock, under the auriferous drift, like graves.

DEADS. Earthy materials without ore—rubbish, refuse.

DEAN. *C.* The end of a driving.

DERRICK. *C.* 1. Miner. 2. A pulley fixed on poles, over which a horse draws a rope by walking forward.

DESAGUADOR. *S.* A pipe or drain for conveying water.

DESMONTE. *S.* Clearing away the surface rock; breaking ore.

DESSUE—DIZZUE. *C.* To cut down the ground by the side of a thin lode in order to take the latter down whole; hence *Dzhu*, to undermine a portion of the rock to be blasted whole; Cornish, *Dyzhue*, to lay bare, to disarm.

DIAGONAL. Greek, *dia*, through, *gonia*, corner. From corner to corner.

DIALLING. The process of surveying a mine with a dial.

DILLUEING. *C.* To wash small ore in a fine sieve.

DIORITE. A greenish granular rock composed of silica, felspar, lime, alumina, magnesia, and iron. A greenstone.

DIP. The slope or inclination of a lode or bed from a horizontal line.

DIPPA. *C.* A small pit sunk on a lode to catch water; a pit sunk on a bunch o:e.

DISH. *C.* A vessel or trough in which the proportion of ore due to the lord of the manor or owner of the soil is measured. In lead mines a trough 28 inches long, 4 inches deep, and 6 inches wide. A gallon measure.

DISK. The projecting plate on a stamp shaft caught by the cam.

DOL. Welsh and Cornish for meadow. *Dolcoch*, or *Dolcoath*, red meadow.

DÔL. A 'dole' or share in an undertaking or property.

DOLERITE. A variety of basaltic rock; a compact mixture of augite and felspar, sometimes granular in structure, but often showing no grains.

DOLLY. *Aus.* 1. An instrument used for breaking and mixing clay in the puddling tub. 2. A log of wood shod with iron, and hung from a tree over a hole; formerly used for crushing quartz.

DOLOMITE. Bitter spar. A mixture of carbonate of lime with more than 20 per cent. of carbonate of magnesia, and from 10 to 20 per cent. of carbonate of iron, forms a compact cream-coloured limestone.

DONK. *N.* Doughy, clayey, or soft earth, found in cross veins and flats.

DOWSING-ROD. A rod, usually of hazel, by which formerly explorers were thought to be able to discover a lode by the tendency of the rod to be inclined by attraction towards it.

DRESSER. 1. The superintendent of persons employed in picking, washing, and dressing ore. 2. Those persons themselves.

DRIFT. A tunnel driven from one part of a mine to another.

DROPPER. A course of ore leaving the lower side of a lode.

DUE. The amount of royalty or ore payable to the lord of the manor or owner of the soil.

DUMB'D. When the grate or sieve in which the ore is dressed is choked up.

DÜRR. *G.* Barren part of a lode or ground.

DURGY. *C.* Anything low or short.

DURNS. *C.* Wooden frames like door frames set in drivings where the ground is loose and weak.

DYKE. 1. A band of hard rock, usually igneous. 2. In the North of England a fault is called a dyke.

EFYDD. *W.* Copper.

ELBOW. A sharp bend in the ordinary course of a lode, from which the latter soon recovers.

ELVAN, or ELVEN. *C.* A band or course of hard felstone or porphyritic rock.

EMBONANZA. *S.* When a mine is being worked to profit.

EMBORRASCARSE. *S.* A barren part of the mine.

END. The farthest end of a driving.

ENTBLÖSSEN. *G.* Uncovering a lode.

EPIDOTE. A mixture of alumina and silica forming a variety of garnet; often of beautiful colour and shape. Chemical composition: silica 37·0, alumina 26·6, lime 20·0, protoxide of iron 13·0, protoxide of manganese 0·6, water 1·8.

ERBHEFSTE. *G.* The deepest part of a mine.

ERUPTIVE. The name given to rocks that have burst through other rocks in a molten state, or that have been thrust up bodily.

ESTANO. *S.* Tin.

EXEMPTED CLAIM. *Aus.* A mining claim allowed to stand idle for a time by a certificate from the registrar, as provided in mining law.

EYE. *N.* The top of a shaft or pit.

FAISCADOR. *S.* A gold washer.

FALSE BOTTOM. *Am. & Aus.* A loose plate put into the stamp box; a floor of iron placed in a puddling machine; a bed of drift holding auriferous drift, and overlying the bed of the latter that usually lies on the bed rock.

FANEGA. *S.* A measure equal to an English bushel.

FANEGADO. *S.* A land measure 90½ fanegados = 100 English acres.

FANG. *C.* An air course along the side of an adit or shaft.

FARM. *C.* The fee payable to the lord of the manor or owner of the soil.

FAST. *C.* The solid rock immediately under the surface drift.

FATHOM. Six feet; a cubic fathom 6 feet × 6 feet × 6 feet is the measure of work in most mines.

FAULT. A line of disturbance or dislocation in strata.

FEEDER. A branch coming into a lode from the upper or hanging side.

FEIGH. Ore refuse.

FELSPAR. The name given to a common constituent of many rocks. It is an intimate mixture of fine silica 60 parts, alumina

18, potash 16, with a little lime and some iron. Most of the clays used to make bricks are decomposed felspar. In colour it is white, pink, and red. It can hardly be scratched with a knife.

FELSTONE. A very compact and uniform kind of felspar.

FERRUGINOUS. Charged with iron.

FEURESSENARBEIT. *G.* Fire-eating work, working upwards towards the surface.

FLANG. *C.* A pick with two points.

FLOATING REEF. *Aus.* Loose masses of auriferous rock.

FLOOKAN, or FLUCAN. *C.* 1. A vein filled with clayey matter crossing the main lode. 2. A parallel vein of the same character. 3. A lode containing a preponderance of clay is called a flookan lode.

FLOOR. Where the lode is bent flat in its downward course and appears like a bed.

FLORAN. *C.* Very fine tin ore, sometimes called flour tin.

FLOUR GOLD. *Aus.* The finest drift of gold.

FLOURING. *Aus.* The covering, in the course of using, of the globules of mercury used in gold extraction with a thin film of the sulphide of some other metal, by which the power of the mercury to intercept gold is lost; also called 'Sickening.'

FLUKE. A rod used for cleaning drill holes before they are charged with powder.

FLUME. *Am.* An artificial watercourse at hydraulic gold mines.

FLUORIDE OF CALCIUM. A mixture of the two simple elements of fluorine and calcium.

FLUTHWERK. *G.* Searching for ore in streams and river beds.

FOOT. *C.* An ancient measure containing 2 gallons, or 60 lbs., of black tin.

FOOTWALL. *C.* The under or heading side of a lode.

FOOTWAY. Shaft with ladders and stages used only for descending and ascending mines.

FORCE PIECE. Timber placed diagonally across a shaft or drift for securing the ground.

FORCQUE, or FORK. *C.* The bottom of the sump, in which the water is collected at the bottom of a mine. In Derbyshire a fork is a prop for keeping up soft ground.

FOSSICKER. A sort of mining gleaner who picks the crevices and cavities of the rocks after the miner.

FOUNDER'S SHAFT. The first shaft sunk at a mine.

FRAME, or RACK. *C.* A gently-sloping board for washing stream tin.

FRIABLE. Easily reduced to powder.

FUNDAMENTAL. A name applied to the lowest or basement strata of the earth's crust as far as at present known, as 1 and 2 in fig. 37.

FURNISHER. A man who furnishes money or machinery to a party of miners, and so becomes entitled to a share of the profits.

FUSE. The prepared tape or cord by which fire is conveyed to the charge of explosive to be ignited.

GAD. *C.* A wedge for splitting rocks.

GAL. *C.* A hard rusty gossan—(Welsh, *caled* = hard).

GALENA. Sulphide of lead—the ordinary lead ore of commerce.

GAMELA. *S.* A large wooden bowl used in dressing ore.

GANG, or GANGUE. *G.* The non-metallic material filling lodes.

GANGWAY. A roadway through the deads or rubbish in a mine.

GARNET. A stone valued for its colour and transparency. It is a mixture of silica, alumina, and the oxides of iron and manganese. See 'Epidote.'

GATCHES. *C.* The final sludge or leavings of tin.

GEFARHT. *G.* The course or direction of a lode.

GIRDLE, or GIRDLE BEDS. *N.* Thin beds of hard close-grained sandstone separated by shale.

GLAUCODOTE. A mixture of sulphur with 11·9 of iron and 24·8 of cobalt.

GLIST. *C.* A dark-coloured ferruginous mineral found in lodes—micaceous iron ore.

GNEISS. A rock composed of quartz, mica, and felspar, in which the different parts are arranged roughly in layers. Mica usually prevails.

GONGE. *Am.* The soft clay lying between a body of ore and the sides of the lode or cavity.

GOSSAN. *C.* The name given to quartz, calcareous spar, and other substances filling a lode when charged and coloured with iron ores.

GRAIN TIN. *C.* 1. Tin ore obtained in grains or pebbles. 2. Finest smelted or block tin.

GRANITE. A rock like gneiss, composed of quartz, mica, and felspar, but the particles or granules are all mixed up together indis-

criminately. In colour, white when quartz prevails, red when there is much red felspar, and green sometimes from the presence of chlorite.

GRANT. Land granted to adventurers for mining purposes.

GRANULAR. Made up of grains or granules.

GRANZAS. *S.* Poor ores.

GRASS. The surface of the mine. Ore brought to grass is ore brought to surface.

GRATE. A perforated plate or iron frame with bars used for separating and washing ores.

GREENSTONE. The name given to a variety of rocks (see 'Diorite'); but some greenstones are very close-grained and compact, as if they had been in a molten state.

GRENA. *S.* Uncleaned rough ore.

GREISEN. The common Saxon name for grey-coloured granitic rock.

GRIDDLE. A larger form of grate.

GRITS. Coarse sandstones.

GROOVE. *D.* A mine.

GROUAN. *C.* The common Cornish name for granite and granitic rocks in Cornwall.

GROUND. Name given to strata bounding a lode, synonymous with 'Country.'

GRUBE. *G.* Mine.

GUAG. *C.* An empty space, or place from which the ore has been extracted. (From Welsh, *gwag* = empty.)

GUARDA. A thin parting between the materials of a lode and the country.

GULCH. *Am.* A deep ravine.

GULLY. *Aus.* The feeder of a creek.

GULPH. Of ore, a large body of ore.

GUNNIES. *C.* Name given to width—one gunnie = 3 feet.

GURT. *C.* Channel to carry water from dressing floor.

GUTTER. *Aus.* The lowest portion of a gold digging, or lead filled with auriferous drift that rests upon the solid rock.

HACIENDA. *S.* House where ore is smelted.

HADE. The dip or underlie of a lode.

HAIARN. *W.* Iron.

HALVANNER. *C.* A dresser of halvans.

HALVANS, HALVINGS, HANAWAYS. *C.* Poor or refuse ore after the best is taken out, usually applied to refuse copper ores.

HANDFARHT. *G.* The descent into a mine by ladders.

HANDWHIP. *Aus.* A contrivance for lessening the weight of water lifted out of a digging by means of a lever and weight fixed to a flexible tree.

HANGING WALL. The upper side of a lode.

HARROW. *Aus.* A pole with teeth fixed on it turned round in a puddling machine to mix auriferous clays with water.

HAULING. Bringing stuff to the surface.

HAZLE. *N.* A tough mixture of sandstone and shale.

HEADING-SIDE. The underside of a lode.

HEAD SWORD. Water discharged through the adit level.

HEAVES. Faults by which the lode is thrown upwards.

HEAVY GOLD. *Aus.* Shotty gold; particles of gold the size of gun shots.

HEAVY SPAR. Sulphate of baryta.

HECHADO. *S.* The dip of a lode.

HILO. *S.* A thin metalliferous vein.

HOGGAN. *C.* The food carried by the miner to the mine.

HOLE. To 'hole' is to make an opening from one part of a mine to another; to pick out the soft underside of a lode or bed preparatory to wedging or blasting the remainder down.

HORIZON. The name given to the place occupied stratigraphically by a bed or series of beds of rock.

HORNBLENDE. The name applied to a group of substances, the general composition of which consists of silica 40 to 50, aluminum 0 to 17, lime 0 to 30, iron protoxide 0 to 30, manganese 0 to 4, potash 0 to 3, soda 0 to 8, fluorine 0 to 1, and a little water. Hornblende varies in colour from white through yellow to green and black. The common varieties are of a greenish cast.

HORNSTONE. A hard silicious rock-like flint. See 'Chert.'

HORSE. *C.* The dead or barren ground by which a lode is sometimes split into two.

HUEL, or WHEAL. *C.* A mine work.

HULK. To hulk a lode is to pick out the soft or best part with picks, leaving the hard portion to be blown down with explosives.

HURDLED ORE. Ore passed through a coarse screen, like a mortar screen.

HÜTTENWERK. *G.* Furnace or smelting house.

HYDRAULIC HOSE. *Am.* The flexible hose now used to direct a stream of water against a wall or face of drift.

IGNEOUS ROCKS. Rocks formed or altered by the action of fire.

INCH—MINER'S. *Am.* A miner's inch of water is the quantity of water which will pass through a horizontal slit one inch wide and twenty-four inches long, with the water in the reservoir standing six inches above the hole. The quantity discharged in twenty-four hours is equal to 2,274 cubic feet.

INTRUSIVE ROCKS. Rocks that have been thrust through other strata.

IRESTONE. *C.* A hard tough stone, usually greenstone.

IRONSTONE CASING. *Aus.* The casing of ferruginous matter usually auriferous, found abutting on quartz reefs.

ITABIRITE. *S.* Micaceous iron ore.

JACOTINGA, JACOTINGS. *S.* The various coloured iron ores associated with and often forming the matrix of the gold in the Brazilian mines. So called from their resemblance to the colours of the plumage of the Brazilian bird, Penelope Jacotinga.

JETTERS. *C.* The horizontal rods or poles connecting the water wheel and the pumps.

JEWELLER'S SHOP. *Aus.* The name given to a very rich patch of gold drift.

JIGGING. A method by which the smaller kinds of ore are dressed, either with a sieve turned by the hand with a peculiar rotatory and vertical motion in water, by which the lighter earthy stuff is thrown off the ore; or the same process performed in a variety of ways by machinery.

JOINTS. The natural divisions or partings of strata.

JUDGE. A staff used for underground measurements.

JUMPER. A drill used by one man by raising and falling.

JUNCTION. The union of two veins or lodes.

KAL. *C.* *See* 'Cal' and 'Gal.'

KANN. *C.* The Cornish name for fluorspar.

KAOLIN. China or porcelain clay. General composition, silica 47·2, alumina 39·1, and 13·7 water.

KAZEN. *C.* A sieve.

KEEKER. An overlooker.

KERNED. *C.* Copper or mundic ore hardened by exposure to the sun.

KERNOW. *C.* Cornwall.

KEVIL. *D.* Spar found in the lead veins of Derbyshire.

KIBBAL, or KIBBLE. The bucket or small barrel used to draw materials out of a mine.

KIEVE, or KEEVE. *C.* The tub in which tin ore is finally tossed or tozed.

KILLAS. *C.* The hard shale or slate traversed by lodes.

KINOULLY. *C.* Loose crumbly ground.

KNOCKING. *See* 'Cob.'

LÂCHE. *F.* Dross.

LAMA. *S.* Fine ore as mud.

LANDER. *C.* The banksman who receives and empties the kibble at the top of a shaft.

LAPPIOR. *C.* The old name given to those who formerly dressed ore with their feet in a buddle—dancers; now applied to dressers of ore.

LAUNDERS. *C.* The troughs by which a stream of water is conveyed to the water wheel, or to any part of a mine.

LAVADOR. *S.* A washer of gold after amalgamation.

LAVADOROS. *S.* Gold washings.

LAVOUR. *F.* A buddle for washing ore.

LEAD. *Aus.* An underground course of auriferous drift generally follows the course or bed of an ancient stream. *N.* A string or course of ore.

LEADER. *C.* The same.

LEADING. *D.* A small sparry vein.

LEARYS. *C.* Emptiness. Old men's workings.

LEAT. A water-course for conveyance of water to a mine.

LEAVINGS. See Halvans.

LENTICULAR. Onion-shaped. Name given to masses of different material found in the midst of rocks.

LEVEL. Name given to a driving or adit underground, along the course of a lode.

LEVELLING. The art of finding the level of one place compared with that of another.

LEY DE ORO, or DE PLATA. *S.* The quantity of gold or silver in the ore.

LIMP. An iron tool for separating the refuse from the ore in a mine.

LINGULIDÆ. The name given to a family of ancient shell-fish from their resemblance in shape to a tongue.

LITTLE WINDS. A lesser or subsidiary shaft in a mine.

LOB OF GOLD. *Aus.* A rich deposit of gold within a small area.

LOCH. *W. & D.* A cavity in a lode; a 'vugh.'

LODE. Anglo-Saxon lead; to lead; lode-stone; a vein or course of material different from the enclosing rock, as explained in the text; a fissure or crack filled with matter, which may or may not be charged with metallic ore.

LODE PLOT. A horizontal or flat lode, or one nearly so.

LOFTY TIN. *C.* Large and rough tin ore.

LONG TOM. *Am. & Aus.* A trough for washing gold, as described in the text.

LOORS. *C.* The sludge left after washing tin ore.

LORD. *C.* Landlord; the owner of the soil or mineral, to whom rent or royalty is payable.

LOST SLOVAN, LOW SLOVAN, LODE SLOVAN. The open trench leading to an adit.

LOTH. *G.* A German weight, about half an English ounce.

MACIZO. *S.* An unworked part of a lode.

MAD WATER. *C.* Water that, through neglect, rushes back to the mine.

MAGNETISM is the name given to the power whereby a magnetic ore of iron, the lode-stone, attracts and retains iron and steel; to iron in its latter form it imparts this same power.

MAGNETIC FORCE is the name given to the tendency which magnetic minerals like those just described have to move, or incline or lie with their length pointing towards that portion of the earth known as the 'Magnetic Pole.'

MAGNETIC POLE. A point on the earth's surface at present a little to the west of the North Pole or end of the earth's axis, and towards which magnetic currents ever flow through the mass of the earth. It is a variable point. In 1580 this spot was 11 degrees to the east, in 1669 it was at the true pole, and in 1835 it was 22 degrees west of the latter.

MANGANESE PEROXIDE. Two parts of manganese combined with three of oxygen.

MANTO. *S.* A single bed or layer of strata.

MARCO. *S.* A weight = 8 ounces.

MAZA. *S.* A stamp head.

MEAR. *D.* A measure along the vein of 32 yards.

MEAT EARTH. *C.* The surface soil that may be cultivated.

METAMORPHOSIS. From the Greek, denoting a change of substance or structure.

METAMORPHIC, METAMORPHOSED. Of an altered character; changed.

MIA-MIA. *Aus.* A screen of brushwood, supported on poles, and placed near a shaft to protect the men from the weather.

MICA. A common constituent of granite and gneiss, composed of about—silica 48, alumina 39·8, and potash 12·2.

MICE-EATEN QUARTZ ORES. Quartz full of holes, once occupied by sulphides, now decomposed and gone.

MOCK LEAD. *C.* Name given to blende, also called 'wild lead.'

MONTANA. *S.* A mountain.

MONTON. *S.* A pile of ore, the weight of which varies in the various mining districts of South America.

MORR. *C.* A gathering of ore in a particular part of a lode.

MUESTRAS. *S.* Samples of ores.

MUN. *C.* A metal or a mine.

MUNDIC. Cornish for any pyrites, more correctly applied to arsenical pyrites; the common ore of arsenic.

MUSCHELKALK. The name given by the Germans to a limestone lying in the midst of the New Red Sandstone or Triassic strata. Supposed to be absent from the 'formation' in Britain.

MWYN. *W.* Mine; ore.

NEBENGANG. *G.* A side lode.

NEEDLE. A pricker; a slim piece of round iron used for making touch-holes for blasting rocks.

NITRIC ACID. A mixture of nitre with sulphuric acid.

NITRO-HYDROCHLORIC ACID. A mixture of nitric acid with muriatic or hydrochloric acid—the latter in its common form being known as spirits of salts.

NIVELS DE AGUA. *S.* Water levels.

NOCKING. *C.* See 'Knocking,' or 'Cob.'

NOGER. A drill commonly used as a jumper.

NORIA. *S.* Buckets fixed on an endless chain for lifting water out of a mine.

OITAVO. *S.* About the eighth part of an English ounce.

OJO. *S.* A bunch or spot of ore.

OLD MEN. The former workers of a mine. The workings left by them are the 'Old Men's Workings,' or, as in Derbyshire, 'The Old Man.'

ORE. The substance specially containing metal.

ORE PLOT, ORE BIN. The place where the dressed ore is kept.

ORPAILLEUR. *F.* A gold washer.

ORO. *S.* Gold.

ORTHOCLASE. The name given to transparent or translucent crystals of felspar, of red, yellow, grey, or green colours. Usual composition, silica 65·4, alumina 18, and potash 16·6, with variable quantities of soda, lime, and iron peroxide.

OVERLAPPING. When a group of strata passes over one or more intermediate groups, and finally rests upon one much older, it is said to overlap.

OVOID. Egg-shaped.

PACKING. *C.* The final dressing of tin or copper ore in a large vat or kieve filled with water.

PACOS. *S.* Mixtures of oxides of iron with ores of silver, usually of a red colour, near the surface. As Colorados or Gossans.

PAIR, or PARE. *C.* A gang of miners of indefinite number, often five.

PALÆOZOIC. Ancient life. The name applied to the strata containing the remains of the earliest organic beings.

PALMA. *S.* Quarter of a vara, or Spanish yard.

PANNIO. *S.* The strata traversed by a lode.

PARCEL. A quantity of ore ready for sale.

PASS. An opening or small road left in the 'deads' of a mine for communication between the face of the stopes and the level below.

PEACH STONE. *C.* A greenish-coloured soft stone; chloritic schist.

PEE. *D.* A piece of lead ore.

PEN, or PEDNAN. *C.* (Celtic for head, or top.) 1. The upper part of a buddle. 2. A deposit of ore selected from a lode.

PEPENADO. *S.* Cleaned ore.

PEPENADORES. *S.* Ore cleaners.

PERMIAN. The name given to the strata lying above the Coal-measures. From the ancient kingdom of Perm, in Russia, where these strata are much developed.

PEROXIDE OF IRON. Three parts of oxygen to two of iron. See 'Sesquioxide.'

PICK. 1. An ordinary tool. 2. To pick good ore out of a heap, hence 'pickers.'

PILCH. *C.* A portion of the lode let to miners to raise ore from on tribute.

PILE. 1. As parcel. 2. A pointed piece of timber. In Australia, a digger who has made money has made his 'pile' of ore.

PILLAR. A part of the lode left standing to support the mine.

PILLION. *C.* Ore that remains in the slag after smelting.

PINTA. *S.* The appearance of a sample of the lode by which the character of the latter is judged.

PIPE. *C.* A long bunch of ore in a lode.

PISOLITE. A rock structure like that of the roe of a fish.

PLACER. *Am.* Name given to gold diggings, or hydraulic mines.

PLATA. *S.* Silver.

PLATE. *N.* Compact shale, separable into thin plates, that divides the limestone beds.

PLOMB D'ŒUVRE. *F.* Silvery lead dressed ready for refining.

PLOMBIFEROUS. Containing lead.

PLOT, or PLAT. 1. A place prepared to receive ore 2. A rough flat bridge over a stream.

PLUMP. Provincialism for 'pump.'

PLUNDER. *G.* Ore refuse.

PLWM. *W.* Lead.

POCHERZ. *G.* Poor ore.

PODAR. *C.* An old name for copper ore.

POLVILLOS. *S.* Good ores.

POLVOULLA. *S.* Black silver.

POL ROZ. *C.* A wheel pit.

POL STEAN. *C.* A tin pit.

PORPHYRY—Porphyra, purple. The name originally given to a red rock, with small white crystals of felspar disseminated in it, derived from Egypt, and now used somewhat vaguely to denote rocks containing felspar, more especially the reddish varieties.

POSTS. *N.* 1. Fine shale beds separating limestone beds. 2. In Welsh slate quarries, unproductive portions of rock.

POTASH. Two parts of potassium to one of oxygen. The potash, or pearlash, of commerce is an impure carbonate of potassium.

POT GROWAN. *C.* Decomposed granite.

POWDERED ORE. Fine ore disseminated throughout a lode.

PREDRAS DE MANO. *S.* Good pieces of ore, sometimes held sacred.

PRÊS. *W.* Copper, or brass.

PRICKER. A thin rod used for keeping an opening through the 'tamping' in a borehole.

PRIDE OF THE COUNTRY. *C.* Rich bodies of ore near the surface.

PRILL. *C.* 1. A piece of pure metal after smelting. 2. To prill is to add rich ore to a poorer sample to improve the quality of the latter.

PRODUCE. *C.* The proportion of metal to 100 parts of ore.

PROSPECTOR'S CLAIM. *Aus.* A larger mining claim than is usually granted, and given to a prospector or discoverer of mineral ground.

PROTOXIDE OF IRON. Two parts of iron combined with two parts of oxygen.

PRYAN. Cornish for clay.

PUETAS. *S.* Strong rock enclosing a lode.

PUDDLING MACHINE. *Am. & Aus.* A machine used for mixing auriferous clays with water to the proper consistency for the separation of the ore.

PULGADA. *S.* An inch.

PULVERISER. A machine for grinding ores fine instead of stamping them

PUPPY. An underground tier or set of pumps.

PURSER. The accountant and cashier at a mine, or the treasurer and secretary combined in one person.

PUTZEN. *G.* Small irregularly deposited spots or bunches of ore.

PYROXENE. See 'Augite.'

QUAJADO. *S.* Dull lead ore.

QUARRY LODE. *C.* A rocky lode, broken by joints.

QUARTZ. Pure silica in a crystallised form.

QUARTZITE. Rock with much silica in a partly crystallised form.

QUARTZOSE. Rock with a good deal of quartz in it.

QUELSCHWERK. *G.* Ore to be crushed.

QUEMAZON. *S.* The bare scorched appearance of the outcrop of a lode standing up above the surface of the adjoining land.

QUERGESTEIN. *G.* Strata crossed at right angles by a lode.

QUICKSILVER CRADLE. See description in book. Chaps. xxxix. and xl.

QUILLATE. *S.* Same as 'carat,' further divided into four granos.

QUINTAL. *S.* Four arrobas, or 100 lbs. Spanish = 101½ English lbs.

QUINTAL METRIQUE. *F.* 100 kilogrammes = 217 English lbs.

QUINTLEIN. *G.* The $\frac{1}{16}$ of an English ounce.

QUITA PEPENCE. *S.* A man placed at the head of a shaft to see that none of the ore is stolen.

RABBAN. *C.* A dry yellowish gossan.

RACE. A watercourse from a stream to a mill.

RACKING. The process of separating ores by washing on an inclined plane.

RAFFAIN. *C.* Poor ore.

RAG PUMP. *C.* A chain pump.

RAKE. *C.* A vein or lode. *D.* A fissure as distinguished from a flat.

RAMO. *S.* A branch from a main lode.

REAL. *S.* 1. A mining district. 2. ⅛ of a dollar.

REBOSADERO. *S.* The crest of a lode.

RED RAB. *C.* Red killas, or slaty rock.

REED, RUSH, or SPIRE. *C.* A reed filled with powder to act as a fuse.

REEF. *Aus* 1. The outcrop of strata. 2. Of a quartz bed, or vein. 3. Of a lode generally.

REEF DRIVE. *Aus.* 1. A cutting through the bed rock in alluvial mining for the purpose of ventilation. 2. For seeking fresh underground gullies.

REEF WASH. *Aus.* The auriferous drift spread over the ground near the junction of two underground leads.

RELIZ. *S.* The wall of a lode.

REMOLINO. *S.* A bunch or mass of ore.

RHOMBOIDAL. A rhomboid is a geometrical figure ▱, which has its opposite sides equal to one another, but all its sides are not equal, nor its angles right angles. It is into this form that rock masses are usually roughly divided by natural joints.

RIB. *C.* A loader, or string of ore in a lode.

RID, RIDDING, or REDDING. Cleaning up anything.

RIDD. *C.* A riddle; a shaft or drift.

RIDDLE, or GRIDDLE. A house sieve.

RIDER. 1. A thin band, vein, or layer, lying a short distance from a lode or bed. 2. The rock lying between the two. 3. The earthy materials of a lode. 4. The rock or country enclosing a lode.

RIPPLE, or RIFFLE. *Am. & Aus.* A board or table with grooves cut in the bottom for the purpose of intercepting the amalgam of gold and mercury.

RISE. To work from the level upwards.

ROCK SALT. The chief source of the salt of commerce. Its general composition is chlorine 60, sodium 40.

ROD SHAFT. The shaft containing the pump rods.

ROOF. See 'Back'—the part of the lode over a miner's head.

ROUGHS, or ROWS. *C.* The second quality of cross tin.

RÔY. *C.* A wheel.

RUBBLE. *D.* Loose stones.

RULLERS. *C.* Underground workers with wheelbarrows.

RUMBA DE LA VETA. *S.* The run or course of a vein.

RUN. 1. Run of a vein or lode. 2. When miners *overrun* their contract. 3. When the sides or roof of a mine *run* in or fall together.

SALLER. *C.* 1. A chamber in a mine. 2. A stage to work on. 3. A boarded channel for water to run in along the bottom of an adit. 4. The floor or stage on which the ladders rest in a shaft.

SAMPLE. A portion of the ore by which its quality is to be judged.

SCAL, or SCALE. *C.* The falling, in flakes or scales, of the walls of a lode after the mineral has been taken out.

SCHIST. A slaty kind of rock, which splits into thin plates along the lines of its bedding. Often applied to imperfectly-formed slate.

SCHORL. Of an ashy or cindery character. The name formerly applied to the black tourmaline. Also applied to granitic rocks with a preponderance of felspar.

SCOVAN LODE. *C.* A tin lode.

SCOVE. *C.* Very pure tin that hardly needs dressing.

SCUN. *D.* A small vein.

SCROWL. *C.* Loose stones of ore at the point where a lode is disturbed by a cross gossany vein.

SEAM. *C.* A horse-load of tin.

SEAT. The bottom of a mine or roadway.

SEARGE, or SERGE. *C.* A sieve.

SEDIMENTARY. Rocks formed by the deposition of sand, mud, clay, &c., in water, are called sedimentary rocks.

SEGREGATION. A form of the law or process of crystallisation by which materials having a liking or affinity for each other segregate, or, separating from other substances, gather together in masses.

SERPENTINE. A stone much valued in building decoration. Of various colours, green predominating, and various shades; capable of a high polish. Usual composition, silica 42·3, magnesia 44·2, protoxide of iron 0·2, carbonic acid 0·9, and water 12·4.

SERVING. *C.* A supply of tin ready for smelting.

SESQUIOXIDE OF IRON. Two parts of iron to three parts of oxygen.

SET. 1. To set a price upon a share in a mine. 2. To set bargains or work to miners.

SETT. The ground taken by adventurers for mining exploration.

SHAFT. A pit sunk from the surface.

SHAKE. *C.* A crack or fissure.

SHALE. An imperfectly-formed schist.

SHAMMEL. A stage for shovelling ore upon, or for raising water.

SHEET. *Aus.* A solid body of pure ore filling a crevice.

SHELF. *Aus.* The uppermost broken surface of the rock under driftal matter.

SHEPHERDING. *Aus.* Keeping possession of a mining claim by doing the least quantity of work on it allowed by law.

SICKENING. *See* 'Flouring.'

SIDE ADITS. A side passage sometimes made when the chief passage is choked with rubbish.

SILICIOUS. Sandy, containing silica, usually flinty.

SILL. *N.* A threshold, or flat surface; a face of hard rock, as the Great Whin Sill.

SINK. 1. A sump, or sink. 2. To work downwards.

SKIMPINGS. *C.* The skimmings of waste off the body of ore lying in the kieve or vat.

SKIT. *C.* A small pump for surface use.

SLIDE. A minor fault or disturbance in a lode.

SLIME-ORE. Fine ore mixed with fine mud.

SLOCKING STONE. A promising stone of ore.

SLOTTEN. *C.* Slovenly, muddy, sluttish.

SLUICE. *Am. & Aus.* A long trough with a loose, rippled bottom, or bottom with holes, for the purpose of catching gold.

SPANGLE GOLD. *Aus.* Smooth flat scales of gold.

SPAR DANTYGI. *W.* Carbonate of lime as dog tooth spar.

SPAR SIWCRI. *W.* Carbonate of lime as sugary spar; the favourite form for lead ore.

SPATHIC. Of a sparry nature. Carbonates of minerals are usually called spathic ores.

SPLINTERY. Rocks that break up into splinters or long sharp fragments are called splintery.

STALACTITE. Hanging encrustations of carbonate of lime, formed by the dropping of water, are called stalactites.

STALAGMITE. The pinnacles or columns of carbonate of lime, formed on the floors of caverns by the water dropping from the points of stalactites, are called by this name.

STEATITE. A stone, usually soft, with a soapy feel, which contains a good deal of talc. Usually of a greyish green colour.

STEMPEL. *W.* A wooden stage, on which to work above a lode.

STOPE. The workings of a mine between the levels assume the appearance of steps or stopes, and the miners working at these are stoping or stepping. When the steps are overhead, like the underside of a staircase, they are overhand stopes; when below the miner's feet they are underhand stopes.

STRAKE. *Am. & Aus.* A long, slightly-sloping board or table, used for the separation of gold from small quartz, &c.

STREK. *C.* Strake, as above, for washing tin ore.

STRICK. *C.* To let a man down a shaft by a windlass.

STRIKE. 1. The course taken by strata at right angles to their dip or inclination. 2. The course or direction taken by strata along their level line.

STRING. A thin course of ore.

STRUCK OUT. *C.* Phrase used when a lode is struck out of its course, or lost.

STUDDLE. *Aus.* A square piece of timber placed in the corners of a shaft between the horizontal framework.

STULLS. Timbers or staging on which rubbish is left in the workings of a mine.

STURT. A bargain that turns out well for the miners.

SULPHATE OF BARYTA. Chemical composition, baryta 66, sulphuric acid 34.

SULPHATE. A combination of a metal with sulphuric acid.

SULPHURIC ACID. Contains hydrogen, sulphur, and oxygen.

SULPHIDE. A combination of a metal with sulphur.

SUMPH, or SUMP. A pit sunk from the bottom of a mine, either to collect water or to prove the lode to a lower depth.

SUN. *N.* A sun vein is a south vein.

SWALLOW. A large cavity in rocks, chiefly in limestones, useful for draining water from mines.

SWITHER. *Am.* A term used in the Wisconsin lead region to denote a crevice or crack branching from a chief lode.

SYENITE. A granitic kind of rock in which hornblende takes the place of mica.

SYNCLINAL. The downward curve of strata, as at 6, fig. 80.

TAILINGS MACHINE. *Aus.* A machine for dressing the tailings, and for obtaining gold from the detritus brought from the washing machine.

TAIL RACE. The channel by which the tail or 'used' water flows from a mill or mine working.

TAILS. Tin ore thrown behind the stamps to be treated again.

TAKERS. Bargainers, contractors, men who take work in a mine; raisers of ore on tribute.

TALC. Chemical composition, silica 62·5, magnesia 33·9, and water 3·6. Usually of a scaly nature, dividing into thin flexible transparent plates, which are occasionally tinged green or yellow; of a soapy feel.

TAMPING, STEMMING. 1. Filling a hole, in which an explosive has been placed, with clay or other matter, which is rammed tightly down. 2. The material used is called tamping, and the bar or rod used is a tamping bar.

TEARY GROUND. Ground that will tear or break up easily.

TEPELATE. *S.* Barren ground; refuse.

TESTERA. *S.* A dyke interrupting the course of a lode.

TICKETING. The purchase of ore at periodical sales by means of tickets or pieces of paper, on which intending purchasers write the price they are willing to pay.

TINNERS. *C.* All Cornish miners.

TIN STUFF. *C.* The name by which tin ore is known in Cornwall.

TITANIC ACID. A combination of the rare metal titanium (a simple element allied to tin) with oxygen.

TITANIFEROUS. Containing titanium, or titanic acid.

TOL. *C.* The portion of ore paid to the 'bounder.'

TOLLER. *C.* An inspector of tin bounds, which are usually marked by holes dug in the ground.

TOMALO. *C.* A big heap of anything. (Welsh, *tomen*, a mound.)

TON OF FIREWOOD. *Aus.* An average of 50 cubic feet of wood.

TOPAZ. One of the precious stones. Chemical composition, silica 35·52, alumina 53·33, and fluorine 17·49 = 108·33. Colourless, but sometimes tinged pale green, yellow, red, blue, by the presence of other substances.

TORTA. *S.* A great heap of silver ready for amalgamation.

TORMENTOR. *Aus.* A wooden axle studded with iron spikes, and turned round in a trough, for the purpose of puddling auriferous clay.

TOURMALINE. A rock substance, in some varieties forming one of the precious stones. Chemical composition very varied and complex, its base being about 40 silica, with 8 boracic acid, and varying proportions of alumina, phosphoric acid, manganese, iron, lime, potash, lithia, lime, and soda.

TOZING, or TOSSING. Shaking or tossing the wet tin in a kieve or vat; the final operation in the dressing of tin ore, in which, by knocking the sides of the vat, the heavy tin ore sinks to the bottom, leaving the refuse on the top.

TRACE. To follow the lode on the surface, and to lay it open by long pits.

TRACHYTE. A variety of felspathic rock, which breaks with a rough surface. It usually contains crystals of hornblende, mica. or felspar.

TRAPPEAN. A name given to felspathic rocks, including basalt, dolerite, diorite, greenstone, felstone, porphyry, and the like, from the step or stair-like nature of their escarpments or outcrops. German, *treppe*, a staircase, or flight of steps.

TRELOOBING. *C.* Stirring the 'loobs' or slime tin in water, so that the lighter mud may run off.

TRIBUTE. A sum payable to the original adventurers by miners who take a portion of a mine to work 'on tribute,' the stuff got being their own when the tribute is paid.

TROIL. *C.* A miners' feast or merry-making.

TUCKER. *Aus.* Work by which a man can hardly live.

TUCKER GROUND. *Aus.* Poor ore ground.

TUFA. A light soft rock, deposited from water containing carbonate of lime, and often found near the base of limestone rocks.

TURNHOUSE. *C.* The point where the miner turn sfrom a cross cut along the course of a lode.

TUT. *C.* Tut work, dead-work, working in barren ground; work not yielding profit; tut-bargain work, work taken at a fixed lump price.

TYE. *C.* 1. A small frame like a strake. 2. An adit or drain.

VAN. Dressing a small quantity of ore by hand for the purpose of testing the quality of the ore and the capacity of the lode beforehand.

VARA. *S.* A Spanish yard = 33 English inches.

VALE, or VAL. The place where the reserve of tin ore is placed to dry before it is put into the smelting furnace.

VELADO. *S.* A mine watchman.

VENA, or VETA. *S.* A lode or vein, as Vena Madre, the Mother Vein.

VESICULAR. Containing numerous vesicles or cavities.

VINEWED, or VINNEY. Copper ore, with a green efflorescence like verdigris.

VITREOUS. Of a flinty or glassy nature.

VOLADORAS. *S.* The grinding stones of one kind of arrastres.

VUGH. *C.* A hollow or cavity in the rock.

WALL of a lode. The boundaries of a lode. See 'Hanging side' and 'Heading side.'

WASH DIRT. *Am. & Aus.* The name given to the beds of drift in which the gold is usually found.

WASHING OFF. (Washing up, *Am. & Aus.*) The periodical final cleaning out of all the gutters and appliances used in alluvial and rock gold mining.

WATER BARREL. A barrel used to wind water at a mine.

WATER BOSS. *Am. & Aus.* The owner or holder of water or water rights, who sells the same for mining purposes.

WATER MEN. Men employed in the extraction of water, especially with the rag and chain pump.

WEELDON. Name given in the Forest of Dean to old ironstone workings.

WHELE, WHEAL, HUEL. *C.* A mine.

WHIM. A drum with a vertical axis (see fig. 6), with rope attached, worked by a horse, for winding purposes from shallow depths.

WHIP AND DERRY. A bucket or kibble drawn up a shaft by means of a rope over a pulley, the rope being attached to a horse who moves straight forward.

WINDS or WINZE. A small shaft sunk from one level to another underground.

WORK. *G. werk.* A mine.

WORKING BARREL of a pump. The part the clack valve or bucket works in.

WORKING BIG. When the lode in working admits of a space 2½ feet wide, so that the miner need not break down any of the adjacent rock.

WYTHERN. *W.* Vein, or lode.

ZIGHER. *C.* A small stream of water running slowly underground.

ZONE. Name given to a belt or band of strata, and to groups of strata distinguished by similarity of organic remains or mineral characteristics.

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